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A Southern Upland Grass-Sedge Bog

An Ecological Study

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A SOUTHERN UPLAND GRASS-SEDGE BOG: AN ECOLOGICAL STUDY

By B. W. Wells, *Professor of Botany*

and

I. V. Shunk, *Assistant Professor of Botany.*

Though of local distribution, one of the most characteristic vegetational scenes in the southeastern coastal plain is that of certain flat upland areas carrying a thick close cover of xeric herbs. These are grasses, sedges, numerous showy herbs, and perhaps to the casual observer most characteristic of all, the bright yellow to red erect leaves of the trumpets (*Sarracenia flava*). Pines of various species may or may not be present. When present they are scattered in an open stand giving the locality a distinct savannah aspect. In fact these localities are widely known among the countrymen as "savannahs". In many instances however, the pines through the activity of man and fire have been completely removed. Then the area takes on the aspect of a prairie. Kerr, an early geologist, repeatedly referred to these latter as "prairies".

This community and habitat cannot properly be described by the very indefinite terms "savannah" or "prairie". Neither do such terms as "flat woods" and "wet or low pine barrens" (for the forested portion), or "grassy open grounds", used by many earlier writers adequately convey conceptions of the true nature of both community and habitat. Yet the real nature may fully and quickly be reached when the familiar term "bog" is applied to this and its related ecological situation. It will be abundantly shown in the data constituting the body of this paper that these extensive areas in the southern coastal plain are upland bogs.

The particular community and habitat, intensively studied, is of especial interest because it is an example of a mature and stabilized upland grass-sedge bog forming a subclimax. This fact is naturally of great significance in relation to the study of succession in the region.

This bulletin deals primarily with a study in succession, initiated by two major factors working separately or together, viz: erosion and fire. The community treated is one of the many vegetational complexes occupying low positions, which characterize the ecologically rich area of the lower Coastal Plain of the Carolinian region.

It might be well to call attention to the intergrading relations which this type of bog community holds to other communities, both in space and time. The southern upland bog is not so sharply delimited as a vegetational entity as the better known northern sphagnum bogs, hence perhaps, the delay in the recognition of its true nature and the uncertainty concerning its place and role in succession.

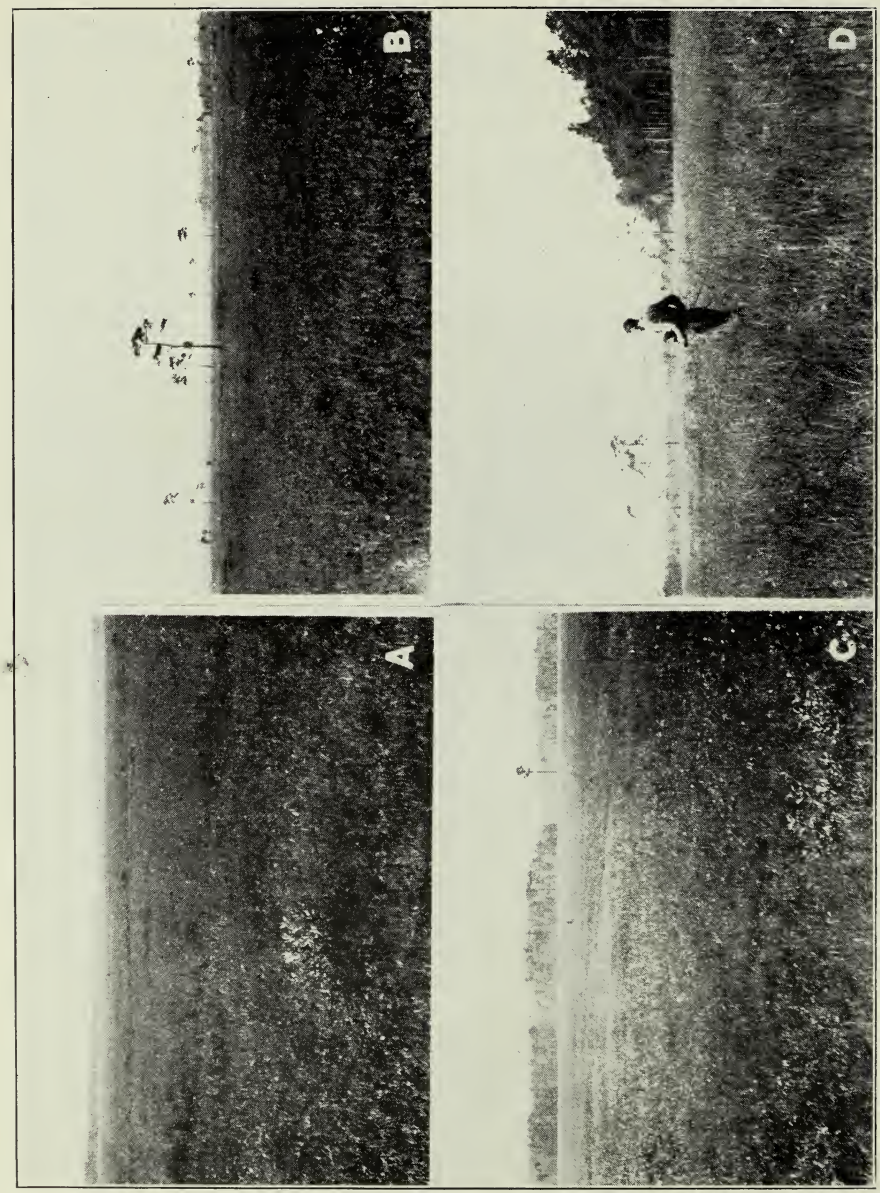


Plate 1. General views of bog. A. Looking northeastward, midsummer aspect. B. Looking southwestward. Note Pinus palustris relicts. C. Looking northward toward site of transect studies. D. Looking westward, Ilex-Pinus consocies of transect study at right.

Plate 2. A. Looking south over bog from transitional zone. B. Woodstock area, Beaufort County, a former grass-sedge bog, now under cultivation. C. Thyrsanthema semiflosculare, first species to flower in spring. Photo taken at 8:00 A. M. D. Same plant as preceding, taken at 10:00 A. M. Note evidence for striking photeolic movement.

The particular associes studied. An outstanding example of the upland grass-sedge bog occurring near the northern limit of this special type of grass-sedge community, constitutes the basis for the present study. The area in question, is located about two miles north of Burgaw, Pender County, North Carolina, where it is locally known as "Big Savannah" (pl. 1, A-D). In size the treeless portion is approximately 2½ miles long by 1 mile wide. The broad upper or easterly end of this treeless area is divided by the longest of the stream basins terminating in it, carrying the swamp forest associes, so that the area assumes the shape of a huge Y (fig. 1). At the westerly or south-westerly end, the open area passes rather sharply into the savannah type with its open stand of pines, (*Pinus taeda, P. palustris*). Unfit for cultivation and never cultivated, these 1600 acres constitute a striking exhibit of this type of herbaceous vegetation in the region. Nothing approaching it in size or maturity of development is known anywhere else in the State, with the possible exception of an earlier area "The Woodstock Savannah", in Beaufort County, North Carolina, now under cultivation (pl. 1, B). Further, on the basis of answers to a questionnaire sent to southern botanists, it is believed that few if any treeless localities of similar size and condition exist; at least none were reported which were comparable with the Burgaw area.

Immediately surrounding this large open space are second growth pine stands broken here and there by the broadleaved swamp forest. Further discussion of the environing communities will be given under the treatment of erosion succession.

A word should be appended concerning the remarkable series of aspect changes on the bog as the season advances. The first flowers appear in February and the last in December. Between these follows one floral display after another, and the area constantly rivals a mountain park in floral beauty (pls. 3-7).

Located on the Wicomico terrace dating from middle Pleistocene time, the bog is now about twenty-four miles from the ocean and has an altitude of fifty-eight feet. The soil is the Portsmouth very fine sandy loam with a non-draining subsoil. It is when wet, black in color. The surface of the bog is rough due to the presence of innumerable low tussocks and ridges. Ant hills 15-20 cm. high, carrying a distinctive vegetation, are scattered over the area.

This striking bog associes is thus seen to be correlated with factors which are classifiable under the three heads: topography, soil, and fire.

Literature. There are but a few papers which specifically mention the tract considered in this paper. Kerr (7) speaks of "the well known Burgaw savannah on the R. R., 25 miles above Wilmington. The origin of savannahs is doubtless the same as that of the prairies of the west; the chief cause of them (here at least) is the want of drainage; and this is partly due to the level surface on which the water is held by the thick growth of grass as by a sponge and partly to a close pasty non-porous soil". Hearn, Hurst and Hardison (5) in the "Soil Survey of Pender County, North Carolina", mention the occurrence of "savannah land" near Burgaw, in connection with the soil type comprising this and related areas, viz: Portsmouth very fine sandy loam.

Of historical interest is the early account of savannahs by John Brickell, 1737 (1), "In several places large Savannas, beautiful to behold, which at certain seasons appear at a distance like so many pleasure gardens, being intermixed with a variety of spontaneous flowers of various colors, such as the tulip, trumpet-flower, princess-feather and several others, with great quantities of grass on them but a coarser and stronger nature than up the rivers where is mostly clover to be met with, notwithstanding horses and other cattle feed very well on the former, and are fat, strong and fit for labor, most seasons of the year.

". . . . . Savannas with variety of beautiful flowers and long grass, a rich black earth where scarce any tree will grow yet produces the best wheat and rice of any land in these parts as has been experienced by the planters.

"I have seen several of these savannas some miles in length and breadth but are little made use of by the planters by reason that they are at some distance from their plantations, some being two, three and four miles from the water side, and are only pasturage for cattle."

Purpose of investigation. The major purpose of the investigation is to enhance our knowledge of succession in the coastal plain complex. The subsidiary aims may be briefly stated as follows: (1) From the present distribution of vegetation to deduce the movement of the respective associes. (2) To quantitatively analyse the habitat factors and build up correlations with the stages of the subseres with the hope that (3) these may be indicative of the controlling factors in the vegetational advance and a beginning at least may be made in the proper interpretation of succession in this series of edaphic transformations. (4) To practically apply this fundamental information in the interests of agriculture.

Method of procedure. Transects. Before taking up the problems of vegetational distribution and habitat analysis, it will be necessary to introduce the particular transects, stakes (unit of transect and marking site of holes for water table readings), and stations which were chosen for the detailed study.

A glance at the map (fig. 1) will show a stream head entering the bog on the west side. Nearby, to the north, the larger, parent and deeper valley traversed the thinly forested margin, where drainage conditions were much more favorable than at any point near the stream head. This locality was chosen for the establishment of the transects. Referring to fig. 2, it will be seen that transect A begins in the open bog (station 1) and at 400 ft. (50 ft. between stakes) reaches station 2, at stake 9 just beyond the margin of the woods, and ending near the head of the swamp branch 300 feet further on at station 3. This transect traverses a tension zone related to a fall of only 75.5 cm. (29.75 in.). Transect B cuts through the shallow end of the stream head from station 5 to station 9 (stakes at 50 ft. intervals), with a maximum relief of 45 cm. (17.75 in.). Transects C and D are ditch transects, i.e. beginning in the open bog they run toward the roadside ditch, the stakes (not indicated) spaced 10 feet apart. Relief (ditch depth) of C, 65 cm., of D, 41 cm. At E, a short transect on the margin only was developed to trace the rapid fall of the water table at this point for contrast with the slower movement at all other stations. The relative po-

Fig. 1. Vegetational map of bog area and environs showing location of transects.

sition of the other stations on the area may be determined by a glance at the map.

Specific methods used in connection with the study of vegetation and habitat may best be presented with the data covering these aspects of the problem.

Acknowledgments. The authors wish to express their appreciation of the valuable suggestions and criticisms offered by Dr. Frederic E. Clements of the Carnegie Institution of Washington. For an introduction to the use of the Goldsmith aerometer we are indebted to Dr. G. W. Goldsmith of the same institution. Many suggestions given us by Mr. L. G. Willis, Soil Chemist of the North Carolina Experiment Station have been most helpful and in addition we wish to acknowledge his kindness in throwing open the Soils Laboratory for certain technical investigations. For assistance in the conduct of the field studies, we are under great obligation to Mr. A. C. Martin and Dr. L. J. Pessin, formerly of the staff of the North Carolina State College Department of Botany and to Mr. C. F. Williams of the Department of Horticulture.

VEGETATION

Method of study. Intensive collecting was done at all seasons in the various community areas and an ecological herbarium made. In nomenclature, the names presented in Small's Flora of the Southeastern United States, the only standard work covering the region, are used. Doubtful species were checked by J. K. Small and certain Scrophulariaceae by F. W. Pennell. Dr. A. S. Hitchcock determined a number of grasses.

The quadrat method as ordinarily used is of little or no value in the study of this vegetation. So massed are the commonly small perennials and so impossible is it to determine the integrity of the individuals due to dichotomous rootstalks, that almost any attempt to deal with such a thick mat of interlaced plants on a quadrat basis is doomed to failure. By the use of the restricted 10 cm. quadrat some results were obtained but it is believed that the conclusions based upon intimate field observations are about as accurate.

Ecological classification. The herbaceous complex constituting the upland community may be divided into three consocies. The first two, the Campulosus and Panicum consocies belong to the bog associes while the third, the Andropogon consocies, is to be referred to as the familiar meadow associes. The first consocies is the great central homogeneous vegetation of the bog proper. At the margin of this on the better drained level areas or on the very gentle slopes to the forest, the bog elements compete with numerous semi-bog herbs which cannot tolerate the conditions of the bog. These latter are so numerous in individuals and species that even though the bog elements enter it freely, this zone may be dealt with as an ecological entity, the Panicum consocies. Similarly on the best drained areas near or on the steeper slopes another vegetation competes with the preceding. This constitutes the Andropogon consocies, the only one which under natural conditions usually represents the Syntherisma-Eupatorium-Andropogon associes or meadow community.

With regard to life form, attention is called to those plants which show in addition to leaf reduction, the vertical appressed orientation of

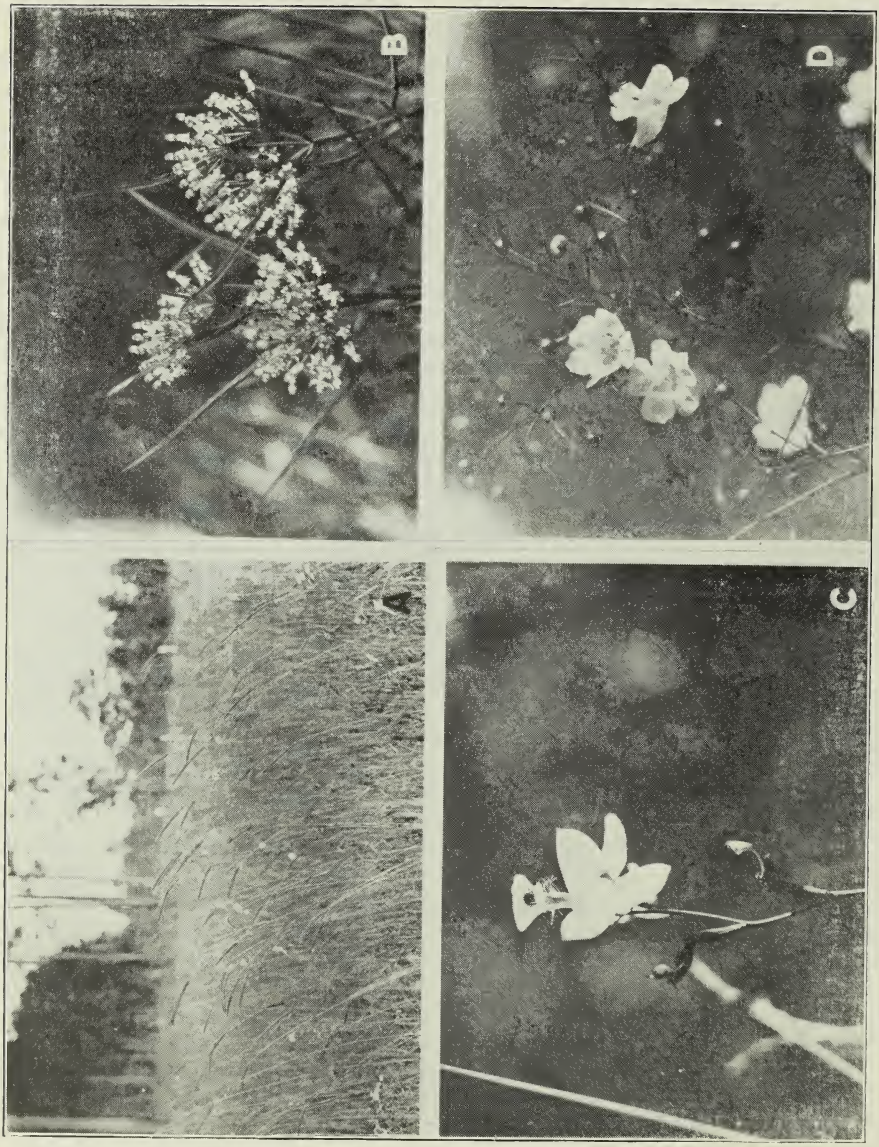


Plate 3. Characteristic species of the Campulosus consocies. A. Campulosus aromaticus. B. Acerates Floridana. C. Limodorum tuberosum. D. Gerardia virgata.

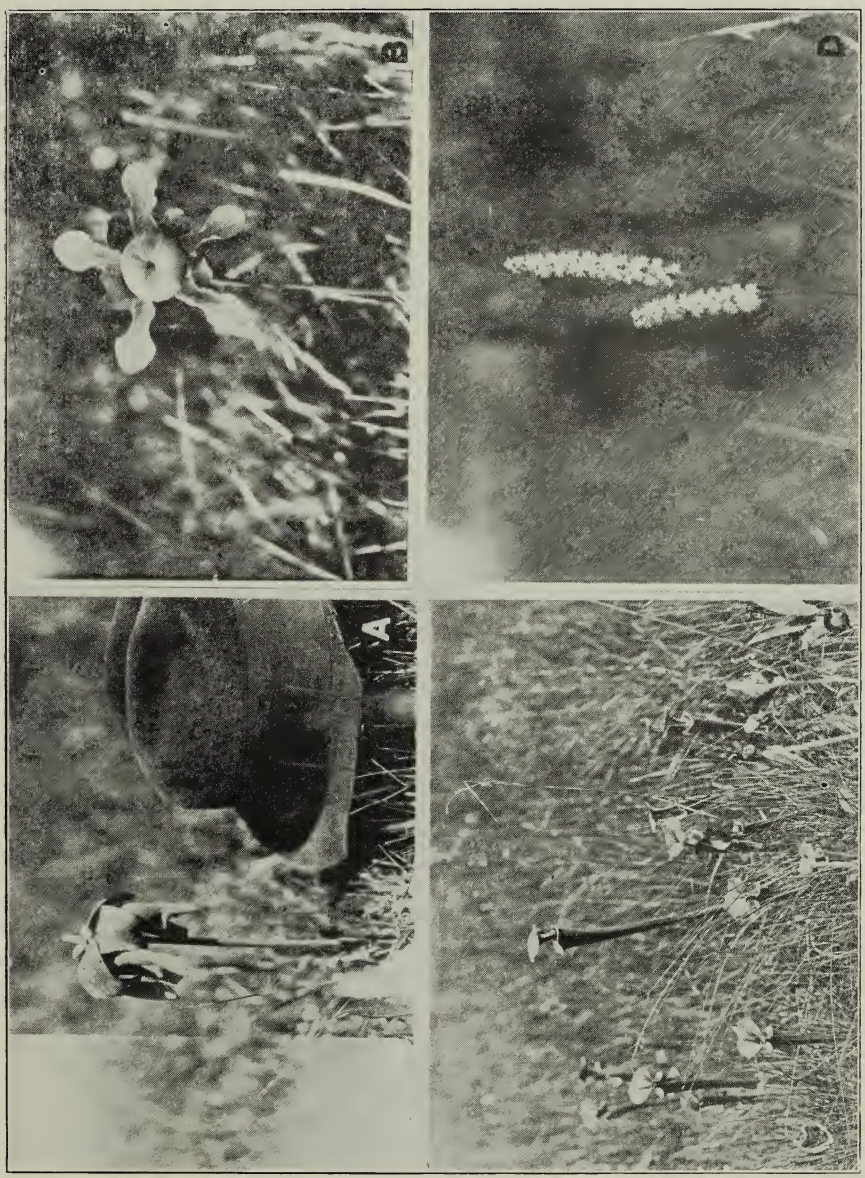


Plate 4. Characteristic species of the Campulosus consocies. A. Flower of Sarracenia flava, drooping type. B. Flower of Sarracenia flava, rare flaring type. C. Leaves of Sarracenia flava. D. Tofieldia racemosa.

the leaves. In a large majority of herbs other than grasses and sedges the cauline leaves lie against the stem in a strict or appressed manner. This appressed character of the leaves constitutes one of the most striking physiognomic characters of the bog proper. In the list, the plants showing this condition are indicated by "A".

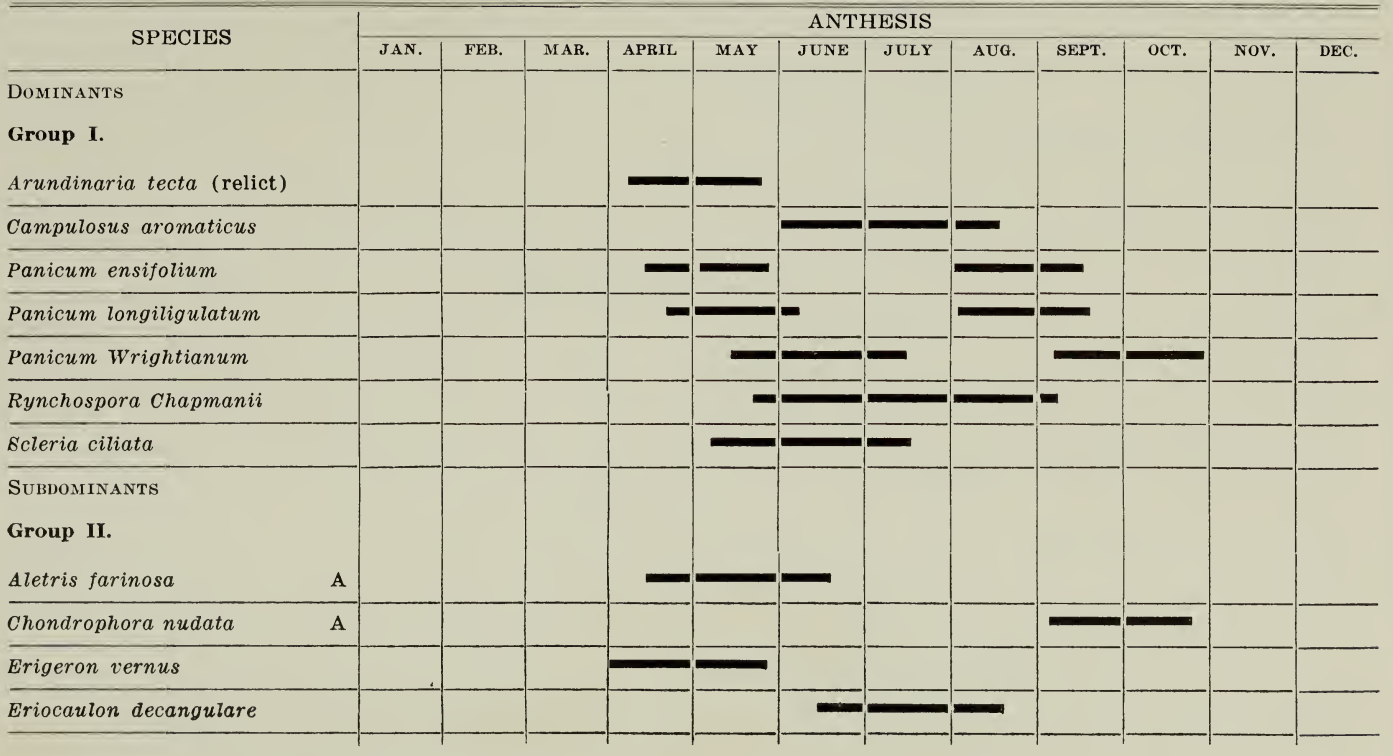
Since the Campulosus consocies constitutes a unique vegetation characterized in part by a remarkable display of floral beauty extending over a period of eleven months, anthesis data have been given for the plants of this consocies.

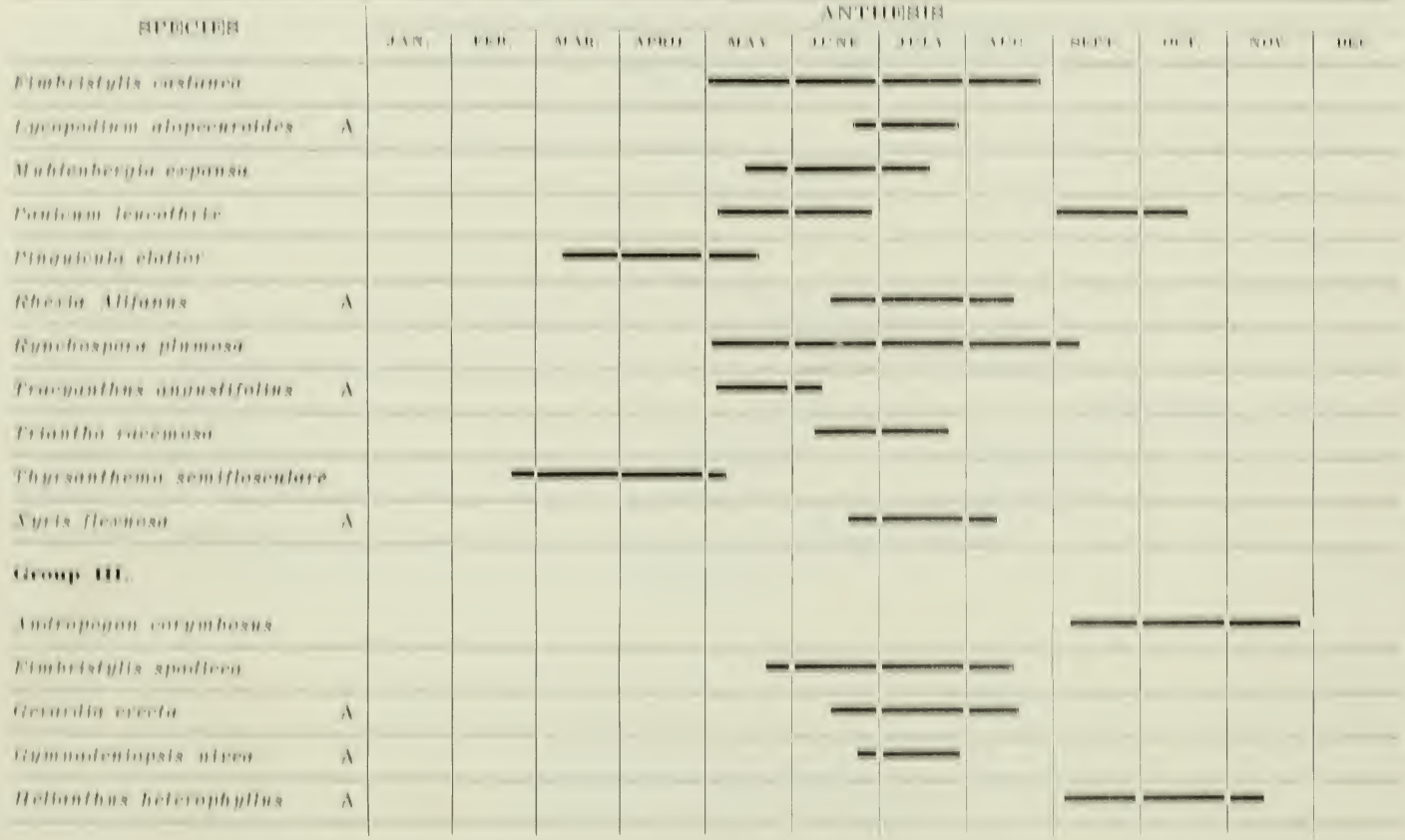
In the following lists, the plants of the three herbaceous consocies are broken up in each list into five groups according to relative frequency of occurrence. This group placing should not be regarded as accurate beyond the adjoining groups, i.e. a species of one group may also exhibit the frequency of the group next to it but for most of the plants, it is not believed that the error in our observations extends two groups or more beyond the one in which the species has been classed.

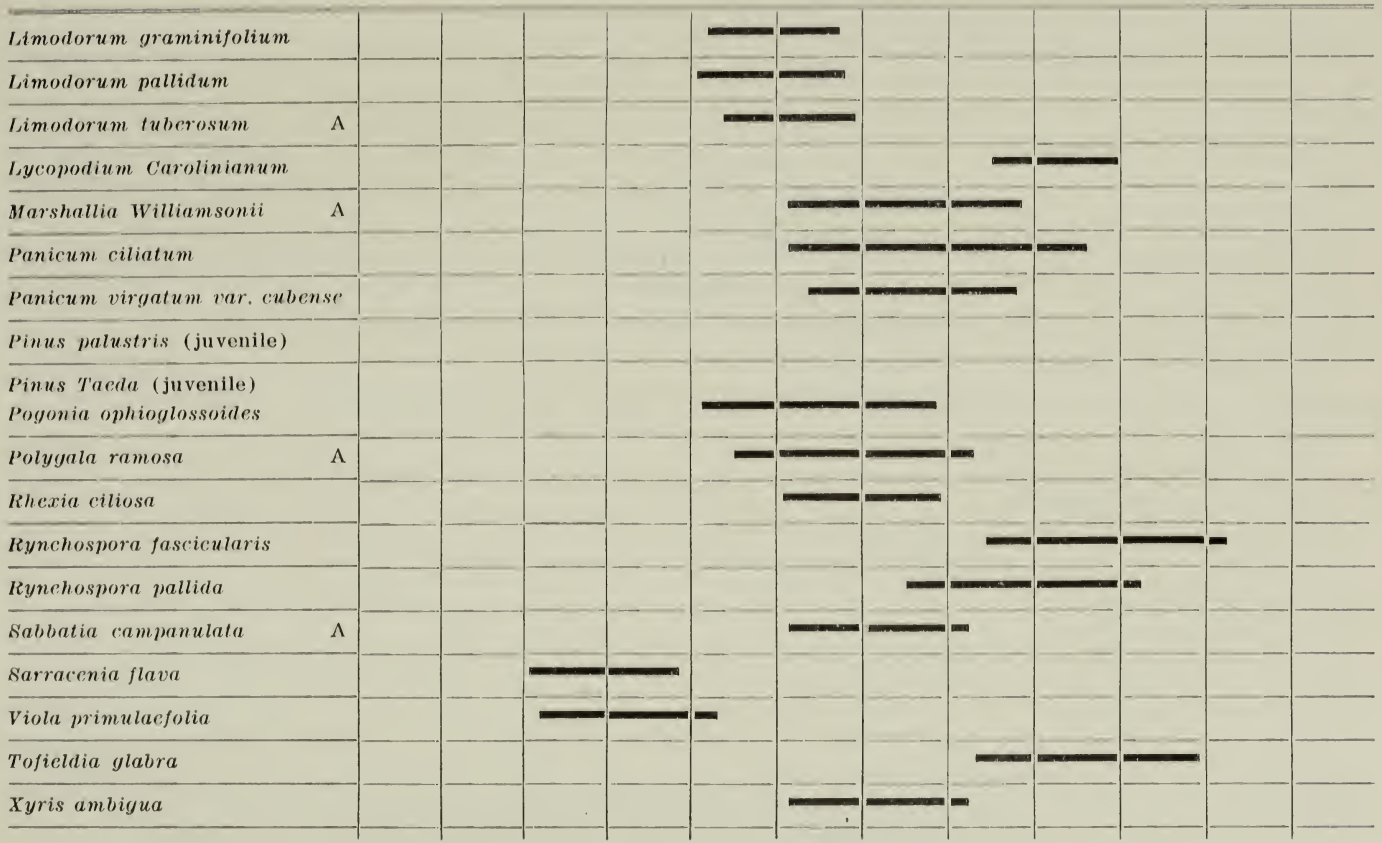
LIST OF SPECIES: The Campulosus-Panicum Associes

Campulosus consocies (bog proper)

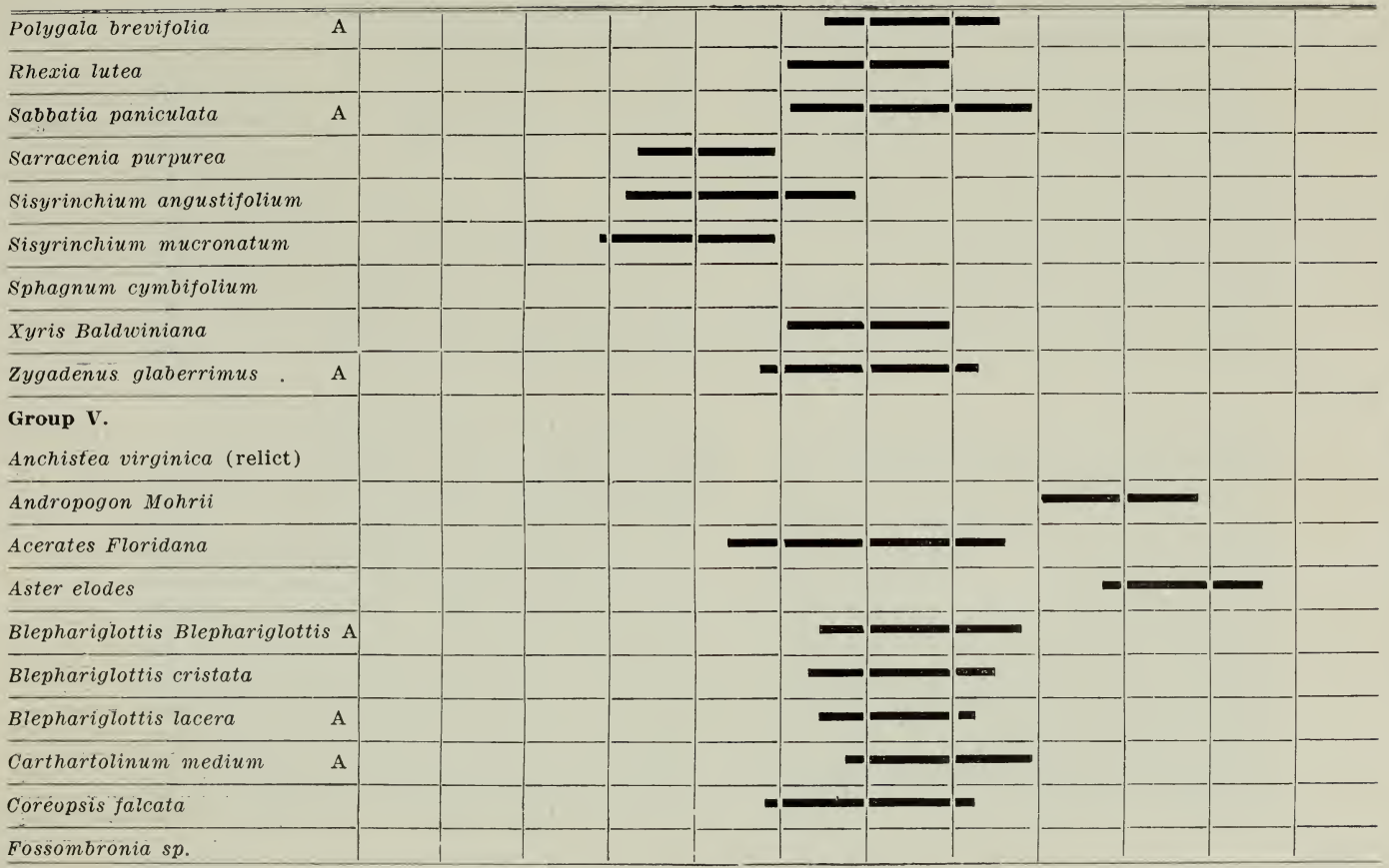
A=*With xeric appressed leaves.*

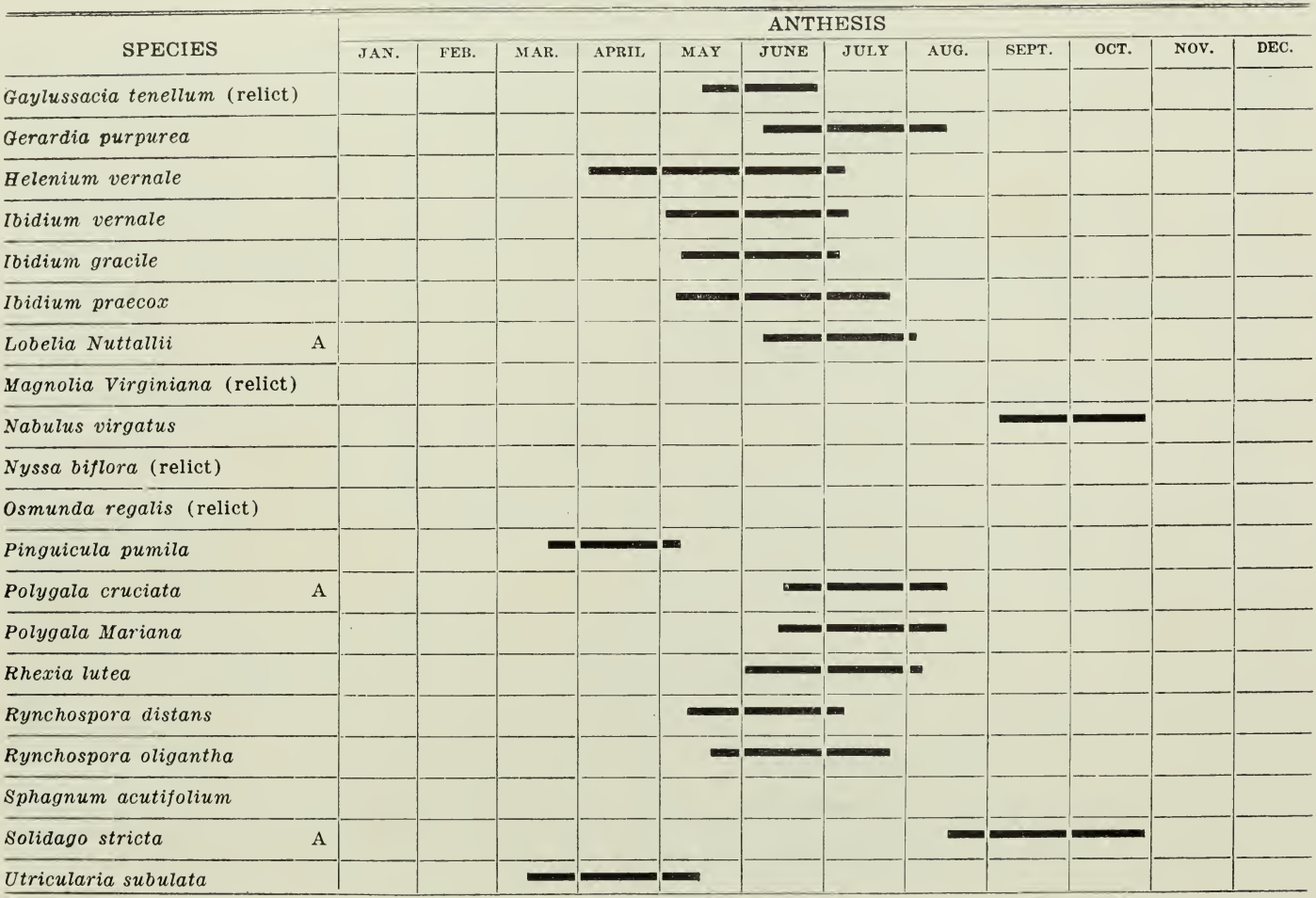



SPECIES
ANTHESIS
JAN.
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
Fimbristylis castanea
Lycopodium alopecuroides A
Muhlenbergia expansa
Panicum leucothrix
Pinguicula elatior
Rhexia Alifanus A
Rynchospora plumosa
Tracyanthus angustifolius A
Triantha racemosa
Thysanthema semifloscularе
Xyris flexuosa A
Group III.
Andropogon corymbosus
Fimbristylis spadicea
Gerardia erecta A
Gymnadeniopsis nivea A
Helianthus heterophyllus A


Limodorum graminifolium
Limodorum pallidum
Limodorum tuberosum A
Lycopodium Carolinianum
Marshallia Williamsonii A
Panicum ciliatum
Panicum virgatum var. cubense
Pinus palustris (juvenile)
Pinus Taeda (juvenile)
Pogonia ophioglossoides
Polygala ramosa A
Rhexia ciliosa
Rynchospora fascicularis
Rynchospora pallida
Sabbatia campanulata A
Sarracenia flava
Viola primulaefolia
Tofieldia glabra
Xyris ambigua

SPECIES	ANTHESIS											
	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Group IV.												
Andropogon perangustatus									▬	▬	▬	
Aster paludosus									▬	▬		
Coreopsis angustifolia A									▬	▬	▬	
Drosera rotundifolia					▬	▬						
Eryngium aquaticum A						▬	▬	▬				
Eryngium integrifolium A								▬	▬	▬		
Gerardia linifolia							▬	▬				
Gerardia virgata							▬	▬				
Helianthus angustifolius									▬	▬	▬	
Hypericum acutifolium						▬	▬					
Hypoxis hirsuta				▬	▬							
Iris tripetala A					▬	▬	▬					
Lilium Catesbaei						▬	▬					
Lycopodium prostratum								▬	▬	▬		
Nyssa sylvatica (relicts)												
Oxypolis filiformis A								▬	▬	▬		


Polygala brevifolia A
Rhexia lutea
Sabbatia paniculata A
Sarracenia purpurea
Sisyrinchium angustifolium
Sisyrinchium mucronatum
Sphagnum cymbifolium
Xyris Baldwiniana
Zygadenus glaberrimus . A
Group V.
Anchistea virginica (relict)
Andropogon Mohrii
Acerates Floridana
Aster elodes
Blephariglottis Blephariglottis A
Blephariglottis cristata
Blephariglottis lacera A
Carthartolinum medium A
Coreopsis falcata
Fossombronia sp.


ANTHESIS
SPECIES
JAN.
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
Gaylussacia tenellum (relict)
Gerardia purpurea
Helenium vernale
Ibidium vernale
Ibidium gracile
Ibidium praecox
Lobelia Nuttallii A
Magnolia Virginiana (relict)
Nabulus virgatus
Nyssa biflora (relict)
Osmunda regalis (relict)
Pinguicula pumila
Polygala cruciata A
Polygala Mariana
Rhexia lutea
Rynchospora distans
Rynchospora oligantha
Sphagnum acutifolium
Solidago stricta A
Utricularia subulata

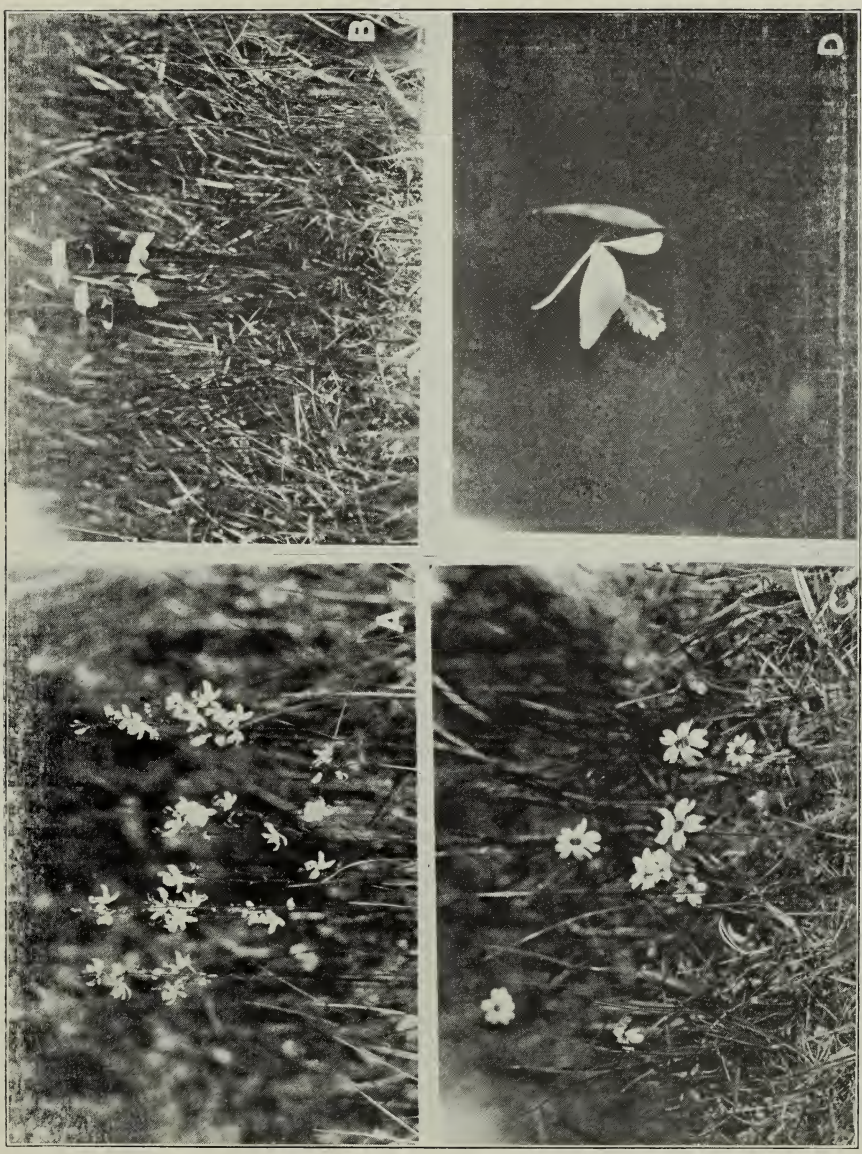


Plate 5. Characteristic species of the Campulosus consocies. A. Limodorum graminifolium. B. Iris tripetala. C. Pinguicula elatior. D. Pogonia ophioglossoides.

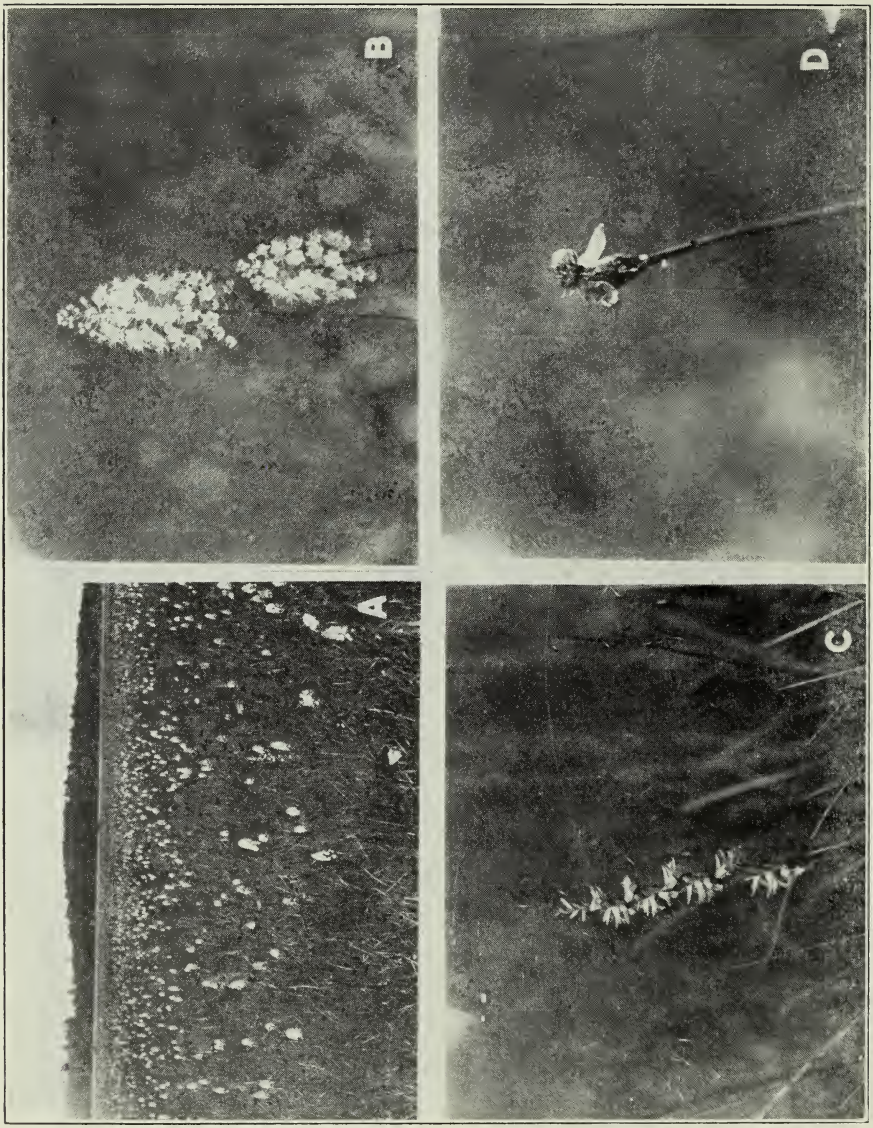


Plate 6. Characteristic species of the Campulosus consocies. A. Tracyanthus angustifolius, general view. B. Inflorescence of preceding. C. Ibidium praecox. D. Xyris flexuosa.

In the preceding list it may be noted that 95% of the species are perennials. The reduction in annuals is probably explained, at least in part, by the destruction of seeds in the yearly fires.

The xeromorphic character of the bog plants is not better observed than in the case of Campulosus aromaticus (pl. 3, A), the bog dominant. Belonging to the Chlorideae, its spike has the same aspect as those related genera of the salt marsh (Spartina) and of the plains (Boutoloua). Like many xeric structures, the head carries a fragrant essential oil, in this instance possessing the odor of oranges. The leaf is of the ridge and groove type.

The roots of the bog plants commonly are reduced in number and exhibit a more or less stunted appearance (pl. 9). These structural conditions are unquestionably a reflection of the unfavorable soil habitat. In this connection it may be noted that aeriferous tissue is prominently represented in the underground parts of these plants, a fact to be correlated with the low oxygen content during the extended flooded periods.

In the depressions between the low tussocks, the frequent occurrence of *Drosera rotundifolia* and *Utricularia subulata* is of interest since these same minute forms are equally common on the inter-ridge areas of the Aristida consocies of certain neighboring coarse sand soils. A brief discussion of this distribution will be given under "Habitat".

The presence of Sphagnum in the form of thin local mats in the depressions, is of interest and tends to connect this bog type with the more familiar northern bogs.

It is notable that no species of Carex has been found in the bog proper. Nor have any fleshy fungi been observed. Another point to be mentioned is the entire absence of legumes.

Of especial interest are the remarkable relicts of *Nyssa biflora* and *Magnolia Virginiana* (pl. 17, D). These trees, especially the first, show extraordinary resistance to fire; the trunks early assume what may properly be called a stoloniferous aspect, lying horizontally half-buried in the ground and sending up each year shoots from 4-10 dm. long. The upper half of the trunks is often burned away but the lower part persists. These fire repressed trunks occur in groups radiating frequently from a common tap root. Using the small annual increment related to the short base as criterion for growth and age, it readily appears that these "trees" bearing but slender annual shoots above the ground are from 30 to 60 years or more old. These curious forms will be discussed further in connection with succession.

PANICUM CONSOCIES (bog transition)

In listing the species of this community (pl. 10, pl. 11, A) we shall only include those which are characteristic of it as distinguished from those also found in the open bog. Most of the bog species range into this consocies but uniformly appear reduced in dominance due to the competition of the marginal species. Thus all of the species given below fade out as the extreme bog conditions are approached. In the transition

Plate 7. Characteristic species of the Campulosus consocies. A. Eryngium aquaticum (white heads near center). B. Lilium Catesbaei. C. Gymnadeniopsis nivea, general view. D. Inflorescence of preceding with flowers of Sabbatia campanulata.

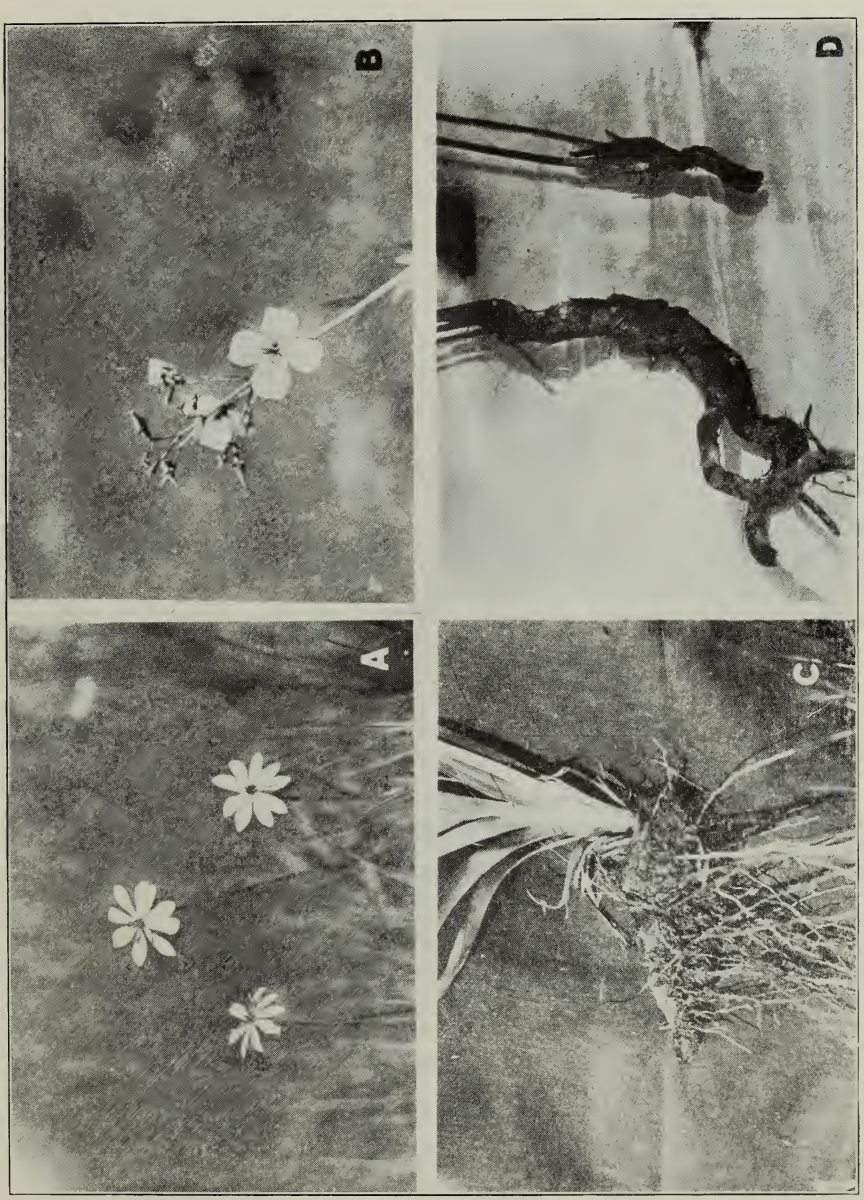


Plate 8. A. Flowers of Sabbatia dodecandra. B. Flowers of Rhexia Alifanus. C. Shallowly buried rhizone of Zygadenus glaberrimus D. Peculiar root of Rhexia Alifanus.

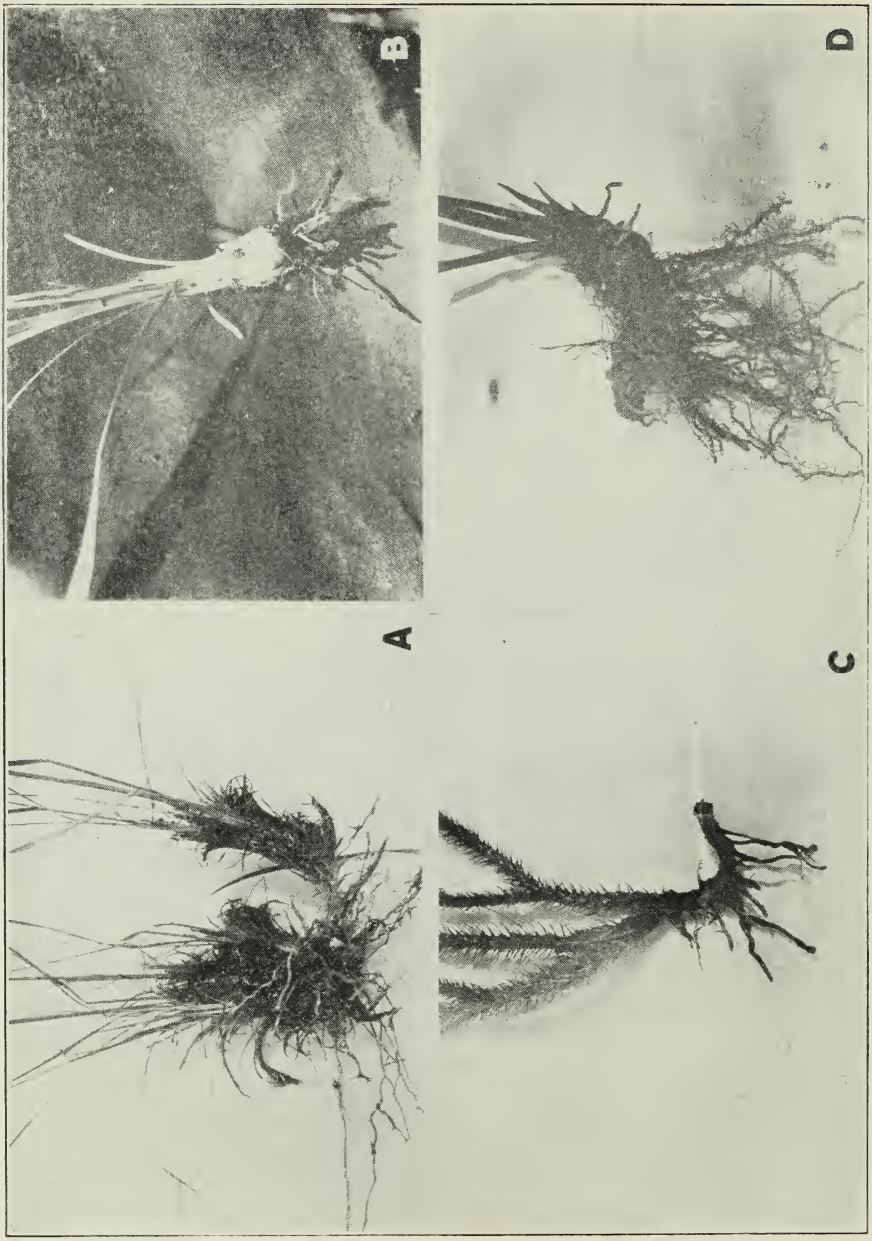


Plate 9. Basal region and roots of typical Campulosus consocies plants. A. Campulosus aromaticus. Note sheath of persistent old leaf and stem bases. B. Lilium Catesbaei. C. Lycopodium alopecuroides. D. Sarracenia flava.

they become reduced in size, number of flowers borne and in general vigor until the edaphic conditions associated with the Campulosus consocies prevent their appearance altogether.

Group I. Dominants

Andropogon scoparius
Panicum consanguineum
Panicum virgatum
Panicum scabriusculum
Panicum Roanokense
Scleria triglomerata

Group II. Subdominants

Andropogon Mohrii
Panicum barulatum
Panicum laxiflorum
Panicum Nashianum
Panicum strigosum
Rynchospora Torreyana

Group III.

Afzelia cassiodes
Aster dumosus var. gracilenta
Carduus Virginianus
Carduus revolutus
Eupatorium rotundifolium
Koellia aristosa
Panicum linearifolium
Panicum barbulatum
Scleria trichopoda

Group IV.

Anthaenantia rufa	
Aristida purpurascens	
Ascyrum stans	
Carduus LeContei	A
Coreopsis gladiata	
Dichromena latifolia	A
Eupatorium leucolepis	A
Helianthus elongatus	
Hypericum acutifolium	A
Hypericum ambiguum	
Hypericum aspalathoides	
Hypericum virgatum	
Lechea tenuifolia	
Lespedeza capitata	
Lysimachia Loomisii	
Polygala lutea	A
Rynchospora Baldwinii	
Rynchospora glomerata	

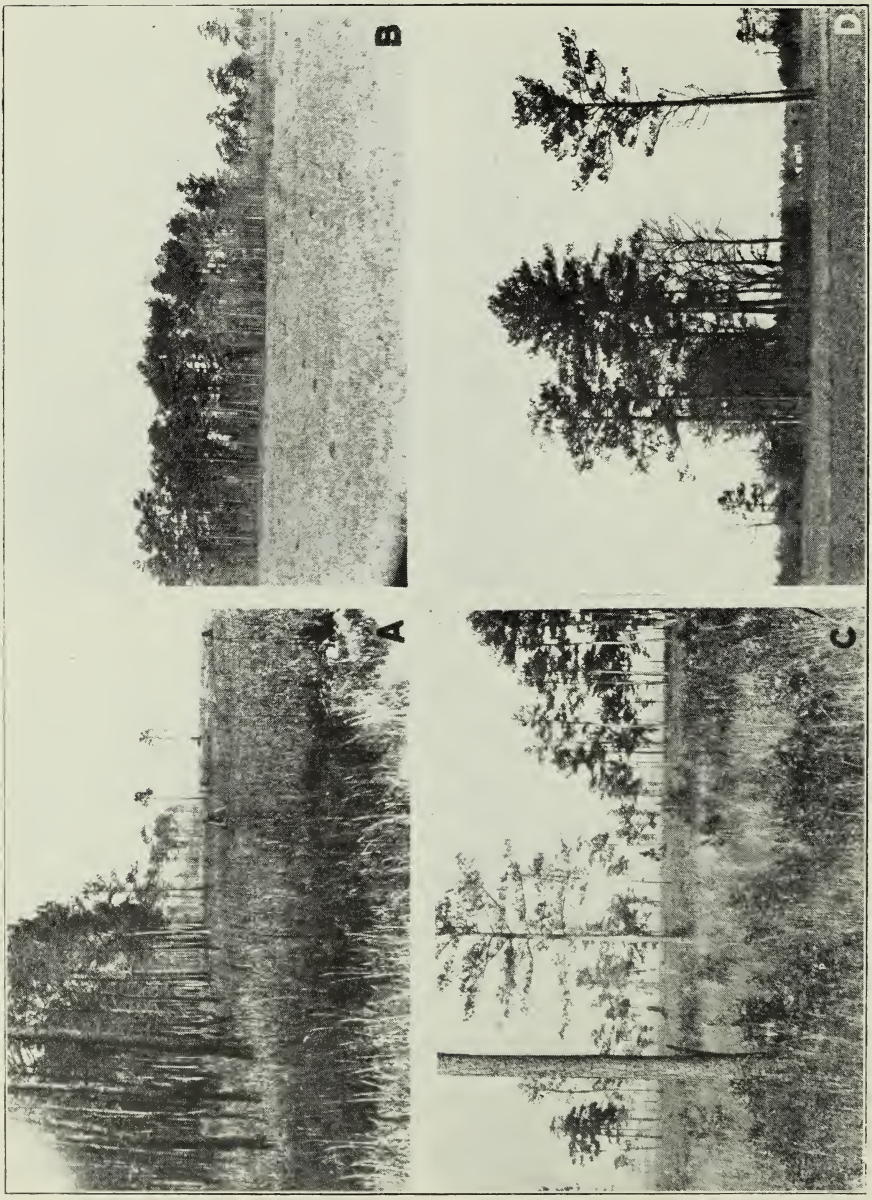


Plate 10. Transition areas. A. Panicum consocies, (right half) with fire tension zone (ecotone) at left. Stump in middle distance gives location of transect A. B. Stream head of shallow drainage basin in and near which the transects were located. C. Flat area with the Panicum consocies. Bog proper in distance. Road not evident, divides unburned zone (foreground) from burned (middle distance). D. Very narrow stream head on south side (Station 15). Burned and unburned zones contrast in foreground.

Sabbatia angularis	A
Sabbatia angustifolia	
Scleria hirtella	

Group V.

Asclepias rubra	
Blephariglottis ciliaris	
Carex crinita	
Chamaecrista nictitans	
Chrysopsis argentea	
Cuscuta sp.	
Dionaea muscipula	
Eupatorium capillifolium	
Erianthus compactus	
Fuirena squarrosa var. breviseta	
Gyrotheca tinctoria	A
Hypericum opacum	
Juncus aristulatus var. tinctorum	
Lobelia amoena	
Ludwigia hirtella	A
Melanthium dispersum	
Meibomia tenuifolia	
Mesadenia lanceolata	
Pinguicula lutea	
Polygala cymosa	
Pogonia divaricata	
Rynchospora rariflora	
Sabbatia dodecandra	
Scutellaria integrifolia	
Solidago patula	
Sorghastrum nutans	
Uniola laxa	

In contrast to the preceding community this one has a much higher number of divaricate leaved plants, 60% of the above list being of this type (not counting grasses and sedges). This change in life form is of especial interest for the plants which constitute the best indicators of the sub-bog habitat are those belonging to this category (*Eupatorium rotundifolium* and others).

A slight change in phase of this consocies may be noted as one passes from the stream head (station 7) to the region of transect A. This is due to the presence in the first and more poorly drained locality of the following minor species suggestive of a marsh flora:

Asclepias rubra	*Ludwigia hirtella*
Carex crinita	*Lysimachia Loomisii*
Hypericum ambiguum	

Mention must be made of the peculiar distribution of Carduus LeContei. In addition to being distributed in the typical localities of this consocies, it is uniformly found on the numerous ant hills which are scattered over

Plate 11. A. Eupatorium rotundifolium (white zone, middle distance) characteristic of the more favorable, better drained zone of the Panicum consocies areas. Ilex-Pinus consocies in background. B. Same site as preceding after removal of pines, exposing the narrow zone of the Cyrilla-Nyssa associes at the center of the drainage basin. C. Andropogon consocies of a narrow interstream area north of the bog. Response to shorter hydroperiod here. D. View from preceding, looking south through trees across the bog.

the main body of the bog. So consistently present is this plant on the ant hills, that it may properly be designated as an absolute indicator of these minor elevations.

The Panicum consocies is distributed on the area mapped along the margin of the woods (station 2), completely across the level area between the stream head and the road, as indicated by station 9 and in general on the margin of the bog wherever open gentle slopes occur.

ANDROPOGON CONSOCIES (mesic meadow)

This consocies (pl. 11, C. D, pl. 12) is the only one of the meadow associes (Syntherisma-Eupatorium-Andropogon) represented under the natural conditions of the bog. The community is characterized by species which are incapable of entering the habitat of either of the preceding consocies. Elements from the Panicum consocies enter freely but those of the Campulosus consocies less so. The plants listed below are only those which are characteristic of this consocies.

Group I. Dominants

Andropogon Elliottii
Andropogon Virginicus

Group II. Subdominants

Aster coridifolius
Lacinaria spicata
Panicum columbianum
Panicum scoparium

Group III.

Panicum rhizomatum
Trilisa odoratissima
Lacinaria gracilis

Group IV.

Aristida Chapmaniana
Meibomia tenuifolia
Solidago juncea
Trilisa paniculata
Chrysopsis argentea

Group V.

Elephantopus tomentosus
Lacinaria graminifolia
Ludwigia virgata
Sericocarpus linifolius
Uniola laxa
Vaccinium crassifolium

This community on the area studied is represented at transect E and on a few other local level well drained areas. It also occurs prominently on fire cleared slopes.

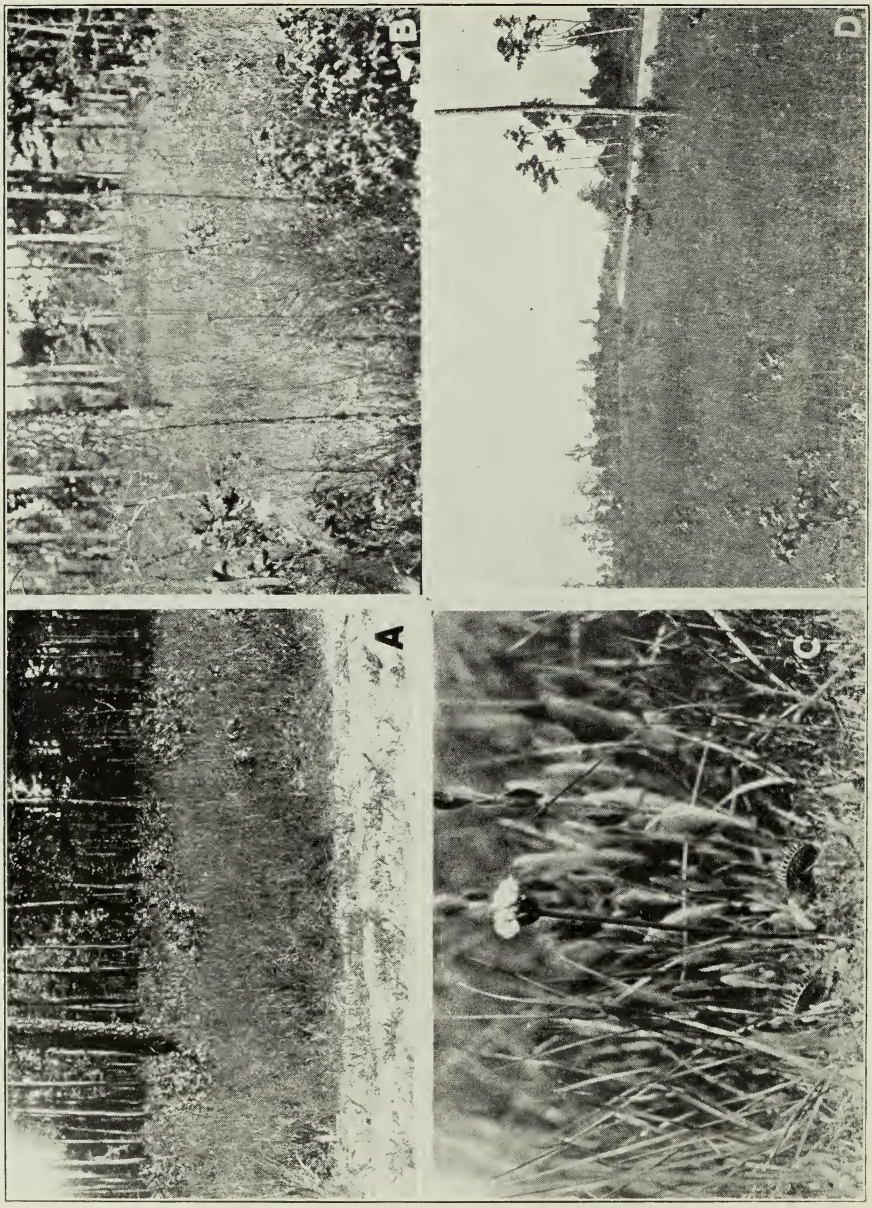


Plate 12. Andropogon consocies. A, View of area immediately east of station 11. B. Trillisa odoratissima in preceding area (slender stems). C. Dionaea muscipula at station 20. D. Mictium of Andropogon and Aristida stricta consocies, Craven County, North Carolina.

As may be noted from the list certain elements from the sand ridge communities are present as subdominants viz: Trilisa and Dionaea. The latter, however, only occurs on the area in the vicinity of station 20.

HABITAT

Climatic factors. It may be stated at once that climatic factors are not involved in the major part of this investigation. This is self evident when attention is directed to the fact that the three consocies of herbaceous communities studied intensively all occur in similar, open areas within a few dozen meters of each other. Nevertheless a condensed statement of climatic data is included because of its value in relation to future local studies of other communities and also because of its value to the student studying a similar or related ecological situation at some distance from the region here involved. The problem of continental distribution is still an open one; how much the rather sharp fading out of the typical bog community in the middle of North Carolina is due to climate and how much to a possible change in soil conditions is not known. Only future workers with adequate data at hand may solve this problem. As a contribution to such data the following is offered here, based upon the U. S. Weather Bureau statements (Day and Denson), taken at Willard, N. C., 8 miles distant from the bog.

Precipitation. The mean precipitation for 14 years prior to and including 1920 was 50.86 inches. The months of greatest rainfall were June and July with 6.15 inches, and 7.45 inches for the entire period.

From Livingston and Shreve the following data have been taken based on the Wilmington records: Total normal precipitation for period of average frostless season, 36.78 inches. Mean normal daily precipitation for period of average frostless season, .158 inches. The number of days with normal daily precipitation of more than .10 inches, 189: with normal daily precipitation of .10 inches or less, 44: percentage of days of latter, 19%. The longest dry period was 23 days, and the longest rainy was 187 days.

In our local study a standard rain gauge was used, the data from which will be given in connection with the discussion of water-table behavior.

Temperature. From the data of Livingston and Shreve based on Weather Bureau records, the period with normal daily mean temperatures of 68° F. or above for Wilmington is 147 days; below 32° F., 0 days. The summary of normal daily mean remainder indices of temperature efficiency for plant growth for the period of average frostless season are as follows: above 0° F., 16,359; above 32° F., 8,903; above 39° F., 7,272; above 50° F., 4,942. The average normal daily temperature for the coldest 14 days of the year is 45° F. The annual mean temperature for 12 years was 61.9° F. The mean maximum temperature was 74.4°, the mean minimum, 49.5°, the highest temperatures recorded (12 year period) 104°, the lowest -2°.

In connection with the study of transect A, temperature records were taken along with those of humidity in the two stations 1 and 2. The record shown in fig. 3 is for four clear days in July.

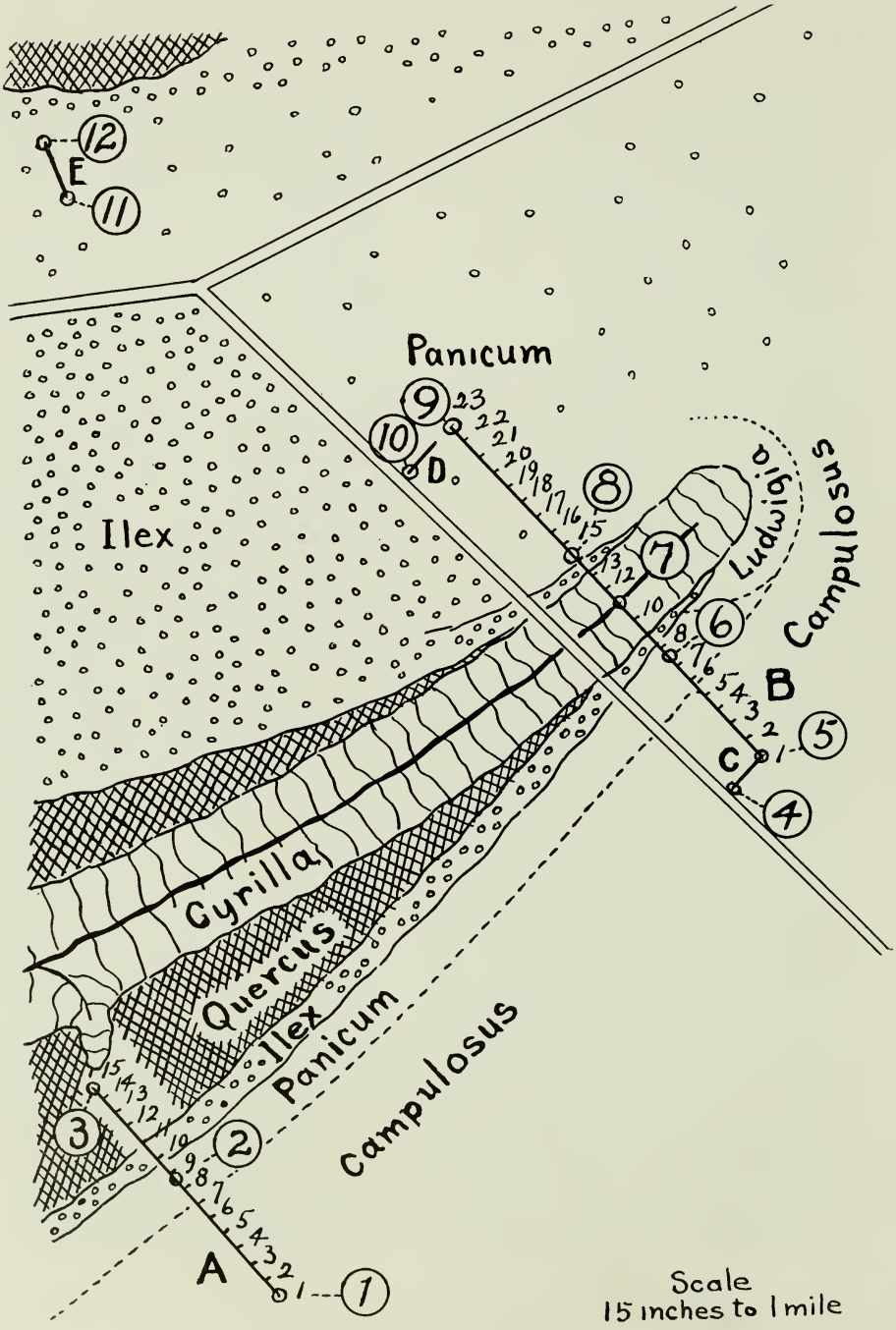


Fig. 2. Vegetational map of stream head showing transects with station and well numbers.

The difference between air temperature and soil temperature throughout the year is always small. The low temperature factor so frequently mentioned in the case of northern bogs is of course not operative in any southern state.

Frost. Willard station. Fourteen-year period. Average date of last killing frost, April 9th. Average date of first killing frost, October 31. Average length of growing season, 205 days. Latest date of killing frost in spring, April 26. Earliest date of killing frost in autumn, October 22.

Sunshine. For the 27 year period of records at the Wilmington station there was 64% of clear days. The normal total duration of sunshine within the period of the average frostless season at Wilmington was 1,942 hours.

With regard to the shade factor some observations were made giving the following percentages based upon records from a stop watch photometer taken around 12:00 m., July 27, 1925. Regarding the full sunlight as 100%, the following percentages of this factor were obtained in various shaded situations:

In shade of vegetation of open bog, station 1	26%
In shade of vegetation of open bog, transect A, stake 7	13%
In shade of *Panicum virgatum*, station 2	6%
In shade of isolated *Pinus palustris* with high branches	50%
In shade of massed *Pinus taeda*	30%
In shade of Nyssa-Cyrilla associes	3%

Humidity. Data taken at Wilmington, 25 miles distant, gives 81% relative humidity at 8:00 a.m., for a period covering 32 years, and 76% at 8:00 p.m. The annual (1908) mean relative humidity at Wilmington was 80.1%; for period of average frostless season, 80.9%; for 3 summer months, 1908, 82%. The mean annual vapor pressure of water, was .471 inches; for average frostless season, .588 inches.

In connection with the investigation of transect A, the two hydrographs available were placed respectively at station 1, and at station 2, which latter was on the outer margin of the Panicum consocies close to the woods. The instruments were shaded in a similar manner by paraffined sheets of muslin cloth and placed on boards resting on the ground (pl. 13, A-B). In fig. 3 is shown a section clipped from the July records, which covers four clear days. The humidity curve (fig. 3) is the one with the flat "peaks" characterizing the middle of the day. As expected the humidity in the middle of the day went consistently lower in the open bog than at its margin.

Wind. With height of anemometer above ground at Wilmington at 91 feet, the average annual velocity of wind per hour for the period 1891-1910 was 8.3 miles. The same, for the average frostless season was 8.0 miles.

Anemometer readings, May 28-June 9:
Station 1, open bog, 719 miles.
Station 2, marginal zone, 401 miles.

Evaporation. Total evaporation for period of average frostless season (1887-1888), was 27.35 inches. The mean daily evaporation for

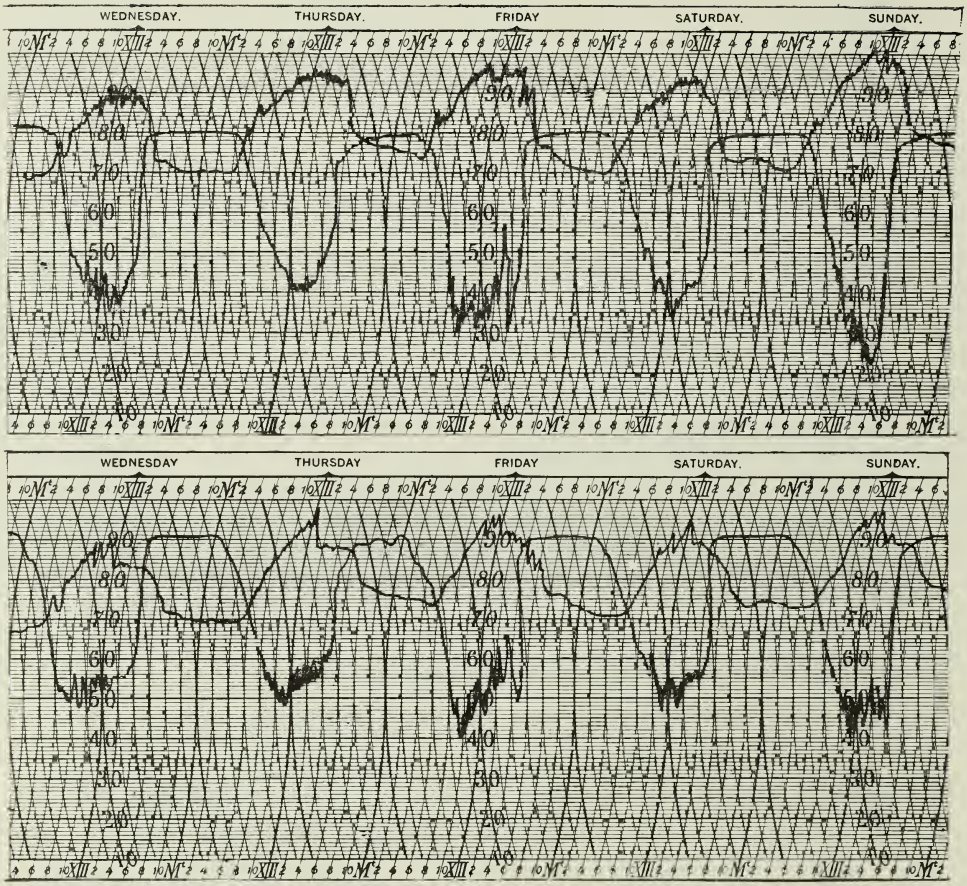


Fig. 3. Hygrothermograph records, stations 1 and 2, July 1-5, 1925, weather clear. Temperature upper line, humidity lower.

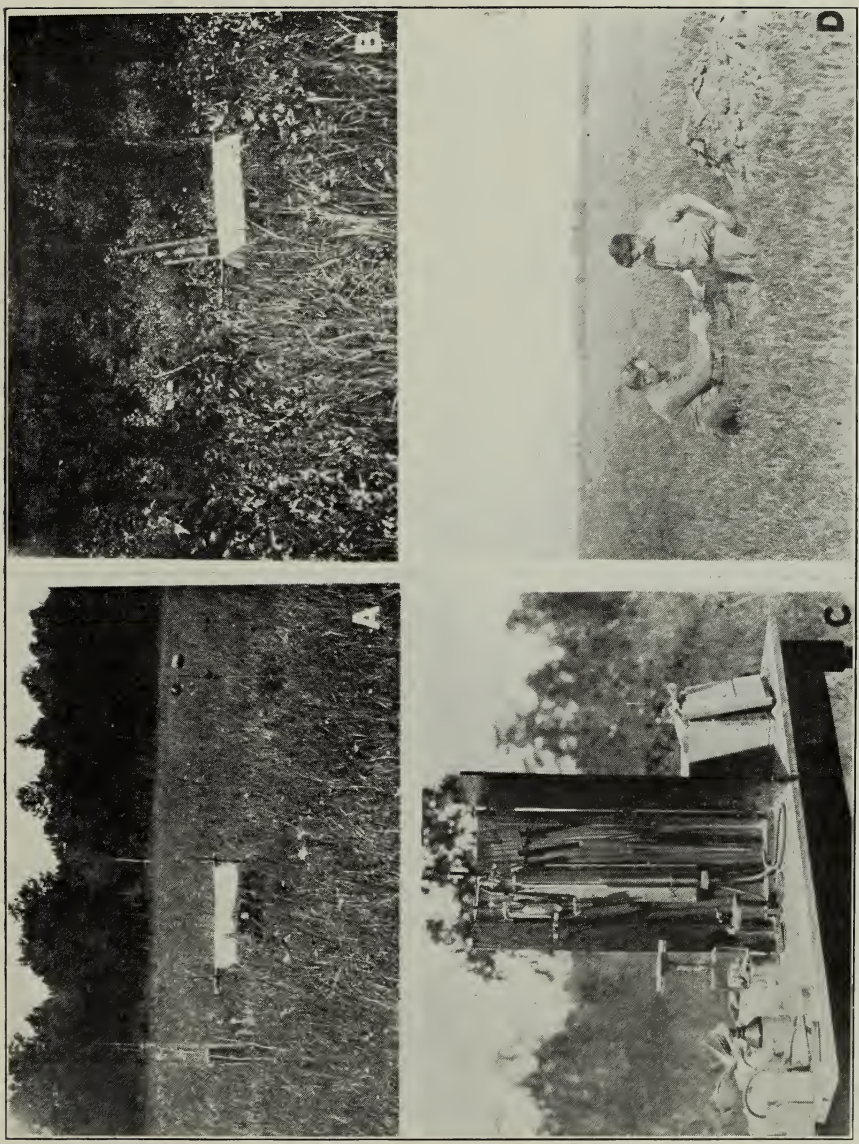


Plate 13. A. Battery of instruments, station 1. B. Station 2. C. Goldsmith aerometer for soil porosity determination. D. Taking soil samples from mid-bog, for aerometer test.

period of average frostless season (1887-1888) was .117. Moisture ratio for period of average frostless season (P/E) was 1.35. This latter figure differs but slightly for the ratio for the entire year which was 1.33. For the three summer months, however, a greater divergence is noted, the P/E ratio being 1.632.

To determine the relative evaporation at different levels in the contrasting habitats, viz.: the open bog (station 1), the margin near the woods (station 2), and in the woods (station 3), Livingston standardized spherical atmometers were used. A modified Pessin mercury valve was used to prevent the entrance of water during rains. All atmometers were exposed to sun with the exception of those at station 2, which were in the shade after 3:00 p.m.

ATMOMETER DATA

ATMOMETER DATA			May 15 to May 28	May 28 to June 9	June 9 to July 28	Total May 15 to July 28
Open bog	High	(110 cm.)	410	329	662	1401
	Medium	(44 cm.)	335	270	549	1154
	Low	(18 cm.)	228	192	382	802
Bog margin	High	(110 cm.)	308	286	506	1100
	Low	(18 cm.)	211	184	185	580
Woods	High	(110 cm.)	222	191	317	740
	Low	(18 cm.)	185	157	235	577

The humidity and wind data readily explain the atmometer results. The atmometer readings are to be correlated directly with the quality of stand of the same species in the different zones. The bog margin plants were strikingly taller and thriftier than those of the open bog, reflecting perfectly the contrasting evaporation conditions. This fact, however, had no relation as far as could be discovered in the distribution of species. Plants of both consocies responded as ecads to the open and protected areas but the species distribution was wholly related to another factor.

EDAPHIC FACTORS

Introduction. The soil constituting the body of the bog (pl. 14, A-B) is classified in the Bureau of Soils bulletin as "Portsmouth very fine sandy loam". Recent studies, however, indicate that this soil may prove to be Coxville. Under the term "Portsmouth" are aggregated a number of black soils of the lower coastal terraces. The various significant soil characters will be brought out in the quantitative analyses which follow.

Mention should be made here of related soils which are known locally to support a similar vegetation to that found on the Burgaw bog: Portsmouth loam, Coxville fine sandy loam, Coxville silt loam, Bladen fine sandy loam, Bladen silty clay loam.

Geological aspects. Since the significant habitat factors controlling the distribution of vegetation just described are edaphic ones, it will be necessary to give an account of the origin of the soil involved; for much of importance in the present factor situation is directly and indirectly related to the physiographical processes of former times.

From the studies of Clark and Stephenson (2), the basic facts concerning the six terraces represented in the coastal plain of North Carolina are well organized so that it has been possible with the aid of personal observations to gain a clear picture of the position of the Burgaw bog area in the terrace system.

The North Carolina seashore during Pleistocene time, due to five successive uplifts of the coastal region, has moved eastward five times, to its present position, adding in the total movement from 100 to 150 miles of former sea bottom to the land area. The five benches or terraces, crudely outlined in fig. 4, are called respectively beginning with the oldest: Coharie, Sunderland, Wicomico, Chowan, and Pamlico. Their development undoubtedly involved most of Pleistocene time.

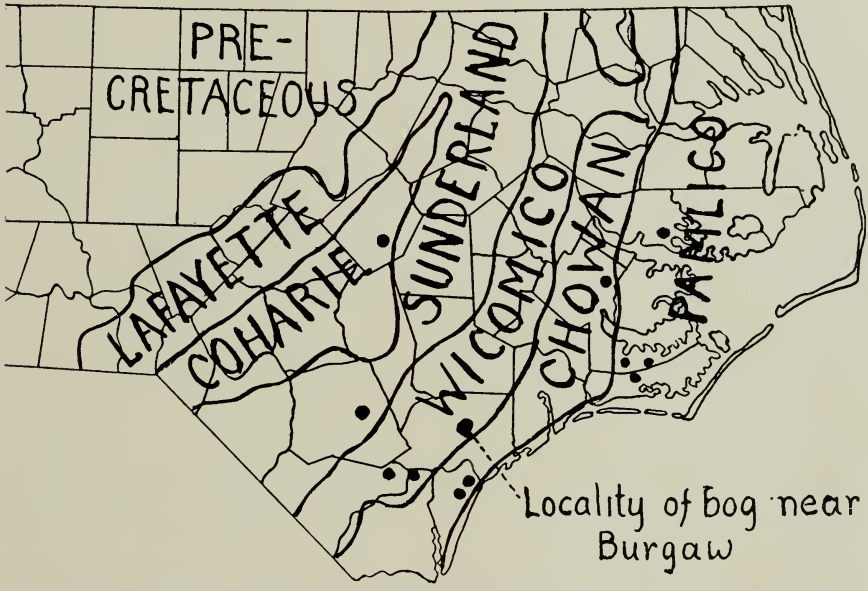


Fig. 4. Crude sketch of coastal plain terraces; no river terraces shown. Black dots indicate approximate location of known grass-sedge bogs involving relatively large areas.

The terrace of especial interest here is the Wicomico, for near its outer margin is located the habitat and community constituting the subject of this study. The terrace at this point is about 27 miles wide, with the Burgaw bog located about 20 miles from its inner margin which marked the former shore line, at the time the Wicomico soils were laid down. This latter is well defined on the main Goldsboro-Wilmington highway, the descent from the Sunderland to the Wicomico being made on a pronounced long slope, 3 miles north of Teacheys. From the former shore line southeastward to the margin, in exact accord with expectations, the sand changes gradually from coarse to fine.

Major topography. The relief of the area is very low. At an altitude of but 58 feet and distant from sea level water some 25 miles, it will be recognized that erosion has gone on very slowly. The character of all of the surrounding drainage basins is that of broad shallow

swamps lying but a few inches to a few feet below the level of the bog. The relief between stations 1 and 3, transect A (fig. 1), is 2 ft., 5.75 in. That between stations 5 and 7, transect B is but 1 ft., 5.75 in. For detailed presentation of the topography see graphs in figs. 5-8.

Minor topography. Under this heading it is necessary to call attention to the tussock character of the bog surface. These tussocks are highly variable in shape, the predominant form, however, taking the shape of curved flat-topped ridges (pl. 18, C). In height the tussocks vary from 3 cm. to 20 cm., the average in the mid-bog falling between 8 and 12 cm. The vegetation of the bog is almost entirely confined to the tussocks, only such minor species as *Drosera rotundifolia* and *Utricularia subulata* being found on the essentially bare areas between the tussocks.

For the origin of the tussocks we must go back to earlier days when the area carried the Nyssa-Cyrilla associes. Under the reduction of this associes by fire, the sphagnum peat masses which filled in the area between the shrub and tree bases, became destroyed leaving relatively large depressions between the stumps of the reduced woody vegetation. Starting with these relatively large tussocks the surface gradually changes to smaller and more numerous ones with the advent of the grass-sedge communities and the crayfish. These latter now come in because of the change in relative permanency of standing water. The bog is much drier in recent time since it has been practically cleared of its woody vegetation and since drainage conditions of the entire region have been improved by man.

Two processes related to the crayfish will explain for the most part the maintenance of the tussock condition on this stabilized area. The deposited material of soil and subsoil at the surface in piles or cones (pl. 18, D), remains intact until taken by the vegetation. This dredging activity of the crayfish is thus of primary significance. Secondly, it has been repeatedly noted that the dark soil exposed in bare intertussock areas is washed by the rain into the abandoned crayfish holes until they are filled. This process though of minor importance tends to enhance the tussock effect.

From the data on the distribution of the crayfish holes presented below, it is of interest to point out that where the holes are absent or infrequent as on the zones paralleling ditches, the tussocks are markedly reduced in height or eliminated altogether. The smooth character of the surface near all ditches is a very striking character and strongly suggests the relation of the crayfish to the tussocks.

In addition to the above, such very minor depressions as those of imprints of fallen trees (near the margin), old deer trails, and wagon ruts, may be mentioned.

Ant hills. Mention should be here again made of these minor topographic features. They are low, conical in shape, and vary from 15 to 25 cm. in height (pl. 18, A-B). One finds them scattered over the entire bog in a fairly uniform fashion; they will average 20-30 feet between them.

Crayfish and earth worm holes. All of the more poorly drained areas exhibit the presence of crayfish. In one 10 meter quadrat 210 holes were counted. The holes go down about 3 feet. Near ditches, of a

number of years standing, the holes decrease as shown by counts made at the road ditch, transect C. In a band 20 feet wide extending along the side of the transect line, in the first 3 feet to stake 11 near the ditch, there were no holes, in the next 10 feet between stakes 11 and 10 there were 3 holes, and successively up to stake 7, the numbers ran 6, 11, 19, and 19. In two similar sized areas in the mid-bog 45 and 64 holes were counted.

No notable decrease in number was found in the transition region from bog to woods along transect A.

Earthworms are present but it is not believed they are common. The occurrence of the earth excreta has been very infrequently noted and the worms are not often observed during digging operations. In this soil type their holes would be well preserved and relatively few of these have been noted. They are not believed to be an important biotic agency in influencing the status of the soil.

Soil Texture. Mechanical analysis of the soil of the mid-bog (Portsmouth very fine sandy loam) gave the following results:

Coarse sand 1-.5 mm.	0
Medium sand .5-.25 mm.	5.4%
Fine sand .25-.10 mm.	24.5%
Very fine sand .1- mm.	70.1%

A bog near Woodstock, N. C., (pl. 2 B), located on the Pamlico terrace was found to be of somewhat coarser texture:

Coarse sand 1-.5 mm.	.79%
Medium sand .5-.25 mm.	14.4 %
Fine sand .25-.10 mm.	26.4 %
Very fine sand .1-mm.	58.4 %

Because of its fine structure the water lifting power of the Burgaw bog soil is very high. It was repeatedly noted that with the water table around 125 cm. depth, the surface soil remained moist. Toward the end of the unprecedented drought of the spring of 1926 the surface became dry, but did not crack.

The data given above explain the fact that the second area is cultivated while the first has never been broken, due to the relation of soil texture to water movement. A relatively slight shift here may be of major importance in the matter of drainage.

Porosity. Using the Goldsmith aerometer (pl. 13, C-D), the following data averages were obtained: (a) Change of surface soil porosity under different heights of the water table.

10.	cm. (4in.) water table, stake 11, ditch transect C	2.2%
20.5	cm. (8 in.) water table, stake 5, ditch transect C	12.5%
25.	cm. (10 in.) water table, stake 3, ditch transect C	12.8%
48.	cm. (19 in.) water table, stake 1, ditch transect C	17.5%
100.	cm. (60. in.) water table, stake 1, ditch transect C	33.3%

These results are expressed graphically in the accompanying figure (9). The sudden drop between the 10 and 20 cm. water table is of course due to the large amount of capillary water in the surface soil, which is formed at these shallower depths, a fact which may also be readily demonstrated by pressing the soil surface with the thumb and

forcing out free water. In such a fine-grained soil it is thus apparent that the effects of flooding extend definitely higher than the water table surface. The conditions created by a high water table are prolonged for a period after the water table falls. In this type of soil the effective flooding is really longer than that indicated by the behaviour of the water table. This fact is of increasing significance where the periods of flooding are longer as in the mid-bog. Here it adds from 1 to 2 days to the effective high water table.

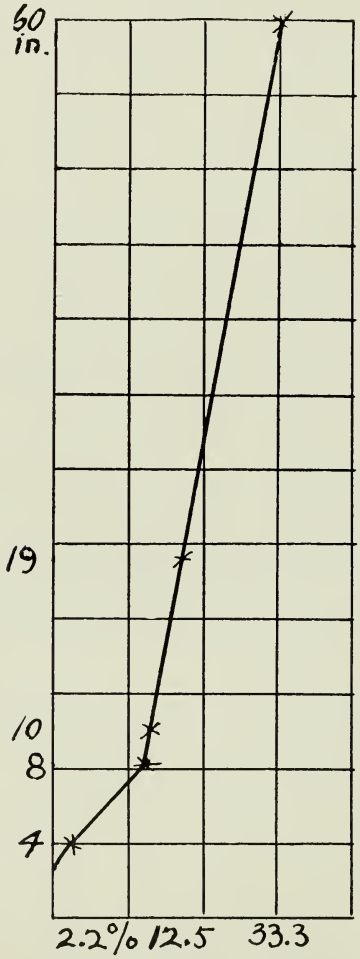


Fig. 5. Graph showing percentages of pore space at surface plotted against the depth of water table.

(b) Change of porosity with increasing depth. Water table over 120 cm. below surface.

Surface	33.3%
15 cm. (6 in.)	17.0%
56 cm. (22 in.)	15.7%
86 cm. (34 in.)	5.6%

The chief significance of these data lies in the relation they bear to the rate of lowering the water table. A glance at the graphs dealing with the fall of the water table in mid-bog will show its rate to increase as the water table falls. This is in large part due to the fact that the water holding space of the subsoil is much lower than that of the upper layers. As the water given up for transpiration and evaporation at the soil surface (none draining out downward), the water table is of course lowered most rapidly in the deeper layers in which less water is found.

(c) Porosity of roadside ditch bank.

Surface 53.6%

This high porosity is to be correlated with the low humus content of this soil.

Chemical analysis. The following report on the chemical analysis of the bog soil is taken from Kerr's report (6) on various soils in North Carolina:

Insoluble residue, Soluble silica	92.66
Potash	.86
Soda	.34
Lime	.22
Magnesia	.40
Peroxide of iron, Aluminum	1.31
Phosphoric acid	.12
Sulphuric acid	.13
Organic matter	4.88
Total	100.92

Water table. From the most superficial observation in any region of low relief under a relatively high rainfall, it is strikingly evident that the distribution of the vegetation is related to the factor of relative permanency of the high water table. This factor will be called in this paper the "hydroperiod", a term derived from the familiar root in hydrophytes, which plants are related to the persistent high water table.

"Hydroperiod" may thus be defined as the time during which the water table is at or near the surface of the soil. By arbitrarily setting a limit (10, 20, or 30 cm. depth) and measuring the time involved in the fall of the water table from the surface to the chosen depth, we have a quantitative expression of great value in dealing with slowly draining lands anywhere. This datum may be designated as the "key or index hydroperiod" as distinguished from the highly variable hydroperiods which occur under conditions of prolonged or frequent rains. The index hydroperiod will be highly constant for a particular local soil area, in so far as the soil drainage conditions are concerned, since the various factors that control soil drainage are highly stabilized and constant. Thus local contrasts in drainage conditions may be dealt with quantitatively by the use of the "index hydroperiod".

One factor functions more or less prominently in lowering the water table, viz.: evaporation, both through the vegetation in transpiration

and directly at the soil surface. Since, however, under the same fundamental type of plant cover (herb, shrub, or forest), the water losses through this agency will be approximately equal in various localities, the hydroperiod data may still be safely used to indicate local contrasts in drainage conditions. An experiment in which the loss from a bare soil surface was contrasted with that from a living sod cover showed the outgo to be practically the same. It must nevertheless be recognized that hydroperiod data because of the evaporation factor, must be used in a relative sense rather than an absolute one. Thus its chief value will lie in the measurement of contrasting but contiguous areas of specific localities.

The lowering of the water table in the mid-bog which was almost entirely due to evaporation during clear days immediately following flooding, proceeded through the surface soil at about 6 cm. per day (24 hrs). Since data from sod transpiration phytometers (cores in containers) gave in the Panicum consocies approximately the same result as that of the mid-bog, the conclusion may be drawn that the more rapid fall in those stations is due to drainage factors proper. Hence, used locally and under similar weather conditions, the hydroperiod method is an extremely valuable one, in spite of the apparent disturbing factor of evaporation.

Before taking up the specific problem of the fall of the water table, attention should be directed to some of the factors involved in the behaviour of the water table on upland habitats. These are rainfall amount, rainfall frequency, topography both major and minor (surface) character), soil and subsoil texture, width of area between drainage basins, and of minor effect relative humidity and wind, as these cause lowering through evaporation.

At A, B, C, and D transects the movement of the water table was observed through a single fall from the flooded bog through a period of 13 days of no rain, following the high water mark of the hydroperiod. For these data see the correlation graphs, figs. 5-7.

It was found impossible in the case of transect B, fig. 6, to satisfactorily show the daily positions of the table on a graph scale which would preserve the appearance of slope, hence the rise of water in the central swamp area appears to go above the level of the environing bog.

The influence of the roadside ditch at transects C and D, is shown in fig. 7.

Especially significant is fig. 8, in which the rate of fall at key stations is shown by plotting the daily movements. The second rise after a fall in the rate exhibited at stations 6, 9 and 4, is due to the immediate runoff; the wave of the latter naturally came on more slowly than that of the former.

The effective hydroperiod in the soil studied is really longer than that indicated by the water table measurements due to the fact that the soil capillaries are choked with water for a measurable distance above the water table. For a detailed discussion of this matter see data presented under "Porosity".

From rain gauge data it was found that for the upper layer of soil one inch of rainfall would raise the water table 25 cm. A four inch rain was once observed to bring the water table from the 120 cm. level to the surface and in addition cause a mass overflow.

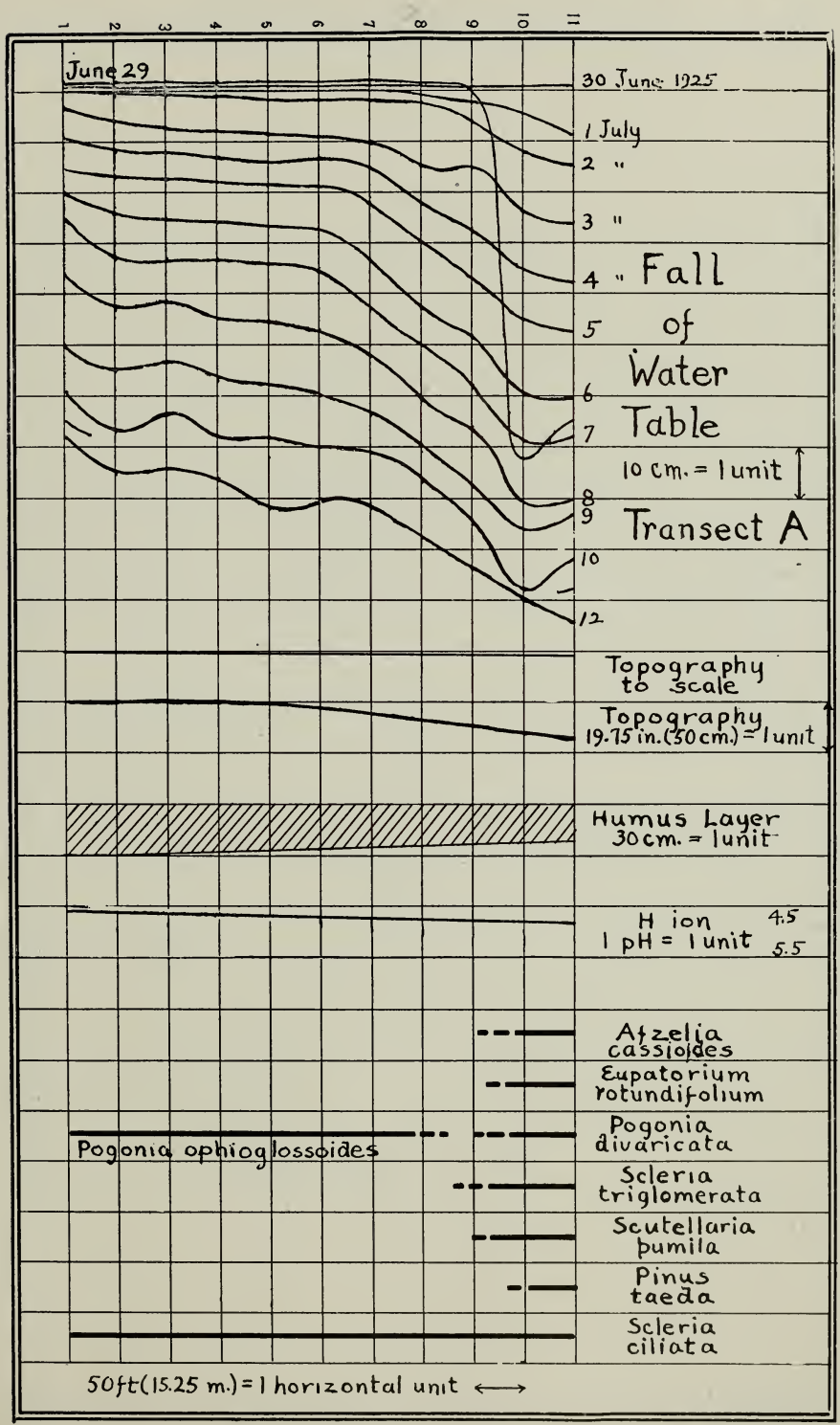


Fig. 6. Correlation graphs of transect A.

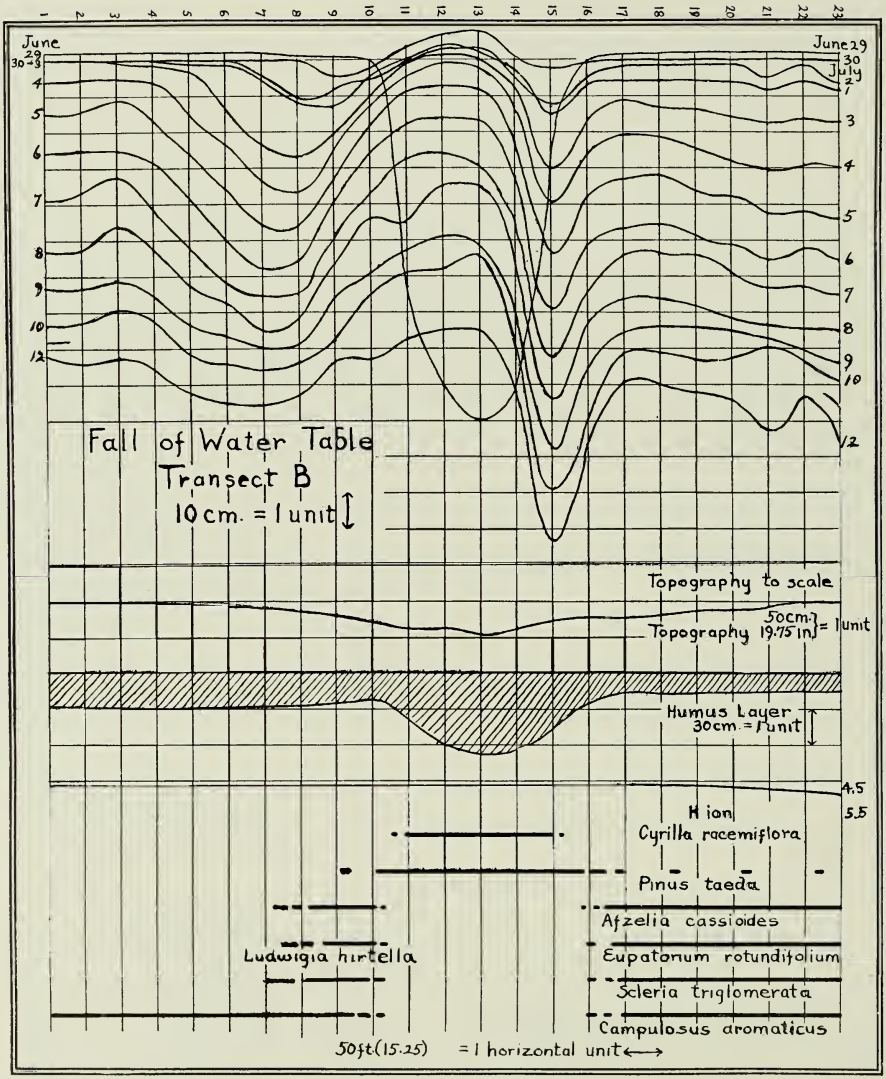


Fig. 7. Correlation graphs of transect B.

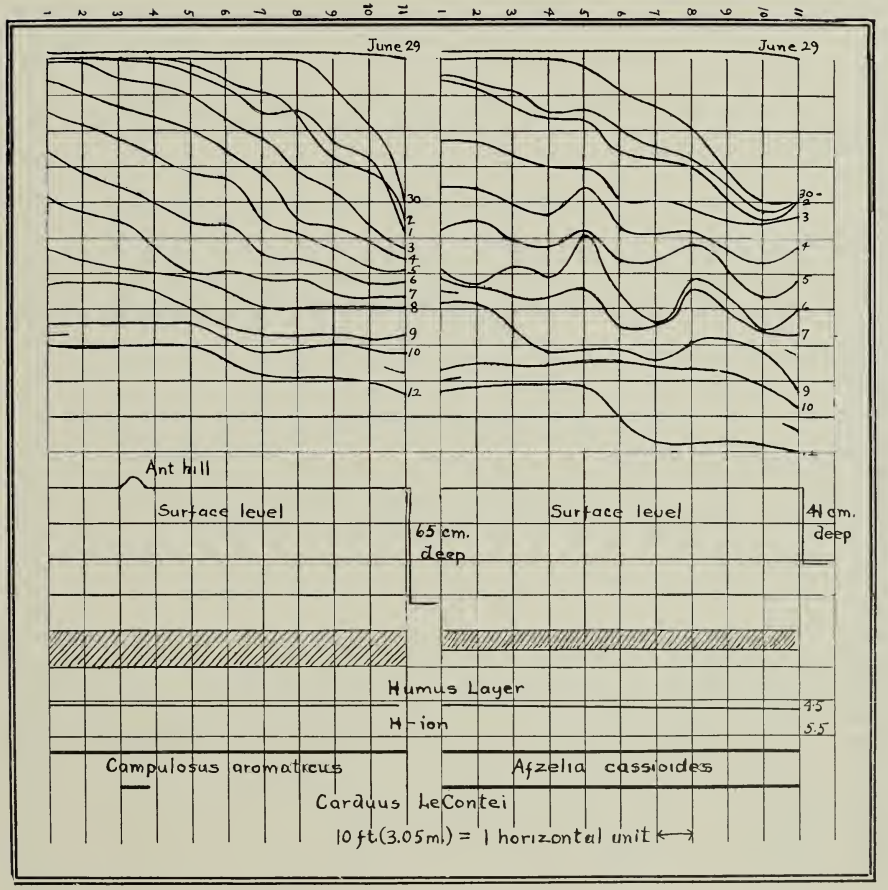


Fig. 8. Correlation graphs of ditch transects C and D.

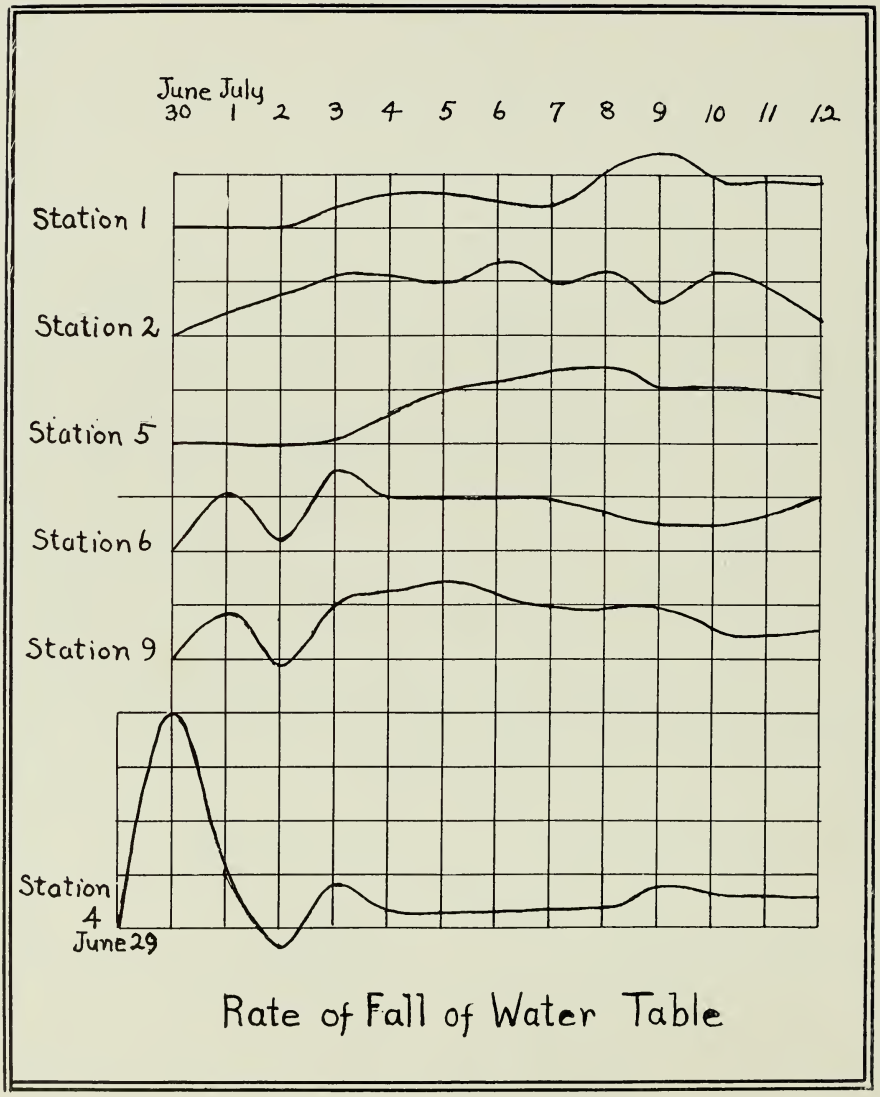


Fig. 9. Graphs showing rate of fall of water table at key stations.

Soil layer showing humus. One of the distinctive features of the poorly drained flat uplands of the coastal terraces is the well defined humus infiltrated soil layer always present. This layer is practically coincident with the soil layer; the large majority of the roots are confined to it, the roots which by their decay maintain it, and increase its thickness in the original mineral soil (pl. 14, A-D, pl. 15, A-B).

The following table presents the thickness of the layer in various upland stations:

Station 1, mid-bog, black	35 cm.
Station 3, margin, dark gray-black	25 cm.
Station 4, 6-yr. ditch side, black	35 cm.
Station 9, level juvenile bog, black	15 cm.
Station 11, margin well drained, gray	7 cm.
Station 13, cultivated field, gray	35 cm.
Station 17, mid-bog east end, black	40 cm.
Station 19, Cyrilla consocies, swamp, black	25 cm.
Station 20, Dionaea area, black	35 cm.
Level area, Andropogon consocies, gray-black, north of Burgaw	10 cm.
Level area, Panicum consocies, gray-black, northeast 1 mile, of Watha, N. C.	17 cm.
Slope, well drained, Andropogon, gray 4 miles west of Willard, N. C.	10 cm.

An outline of the conditions controlling humus accumulation is presented here. It will be desirable to refer to it later in the discussion of succession. The figures pertaining to the thickness are of course only approximate.

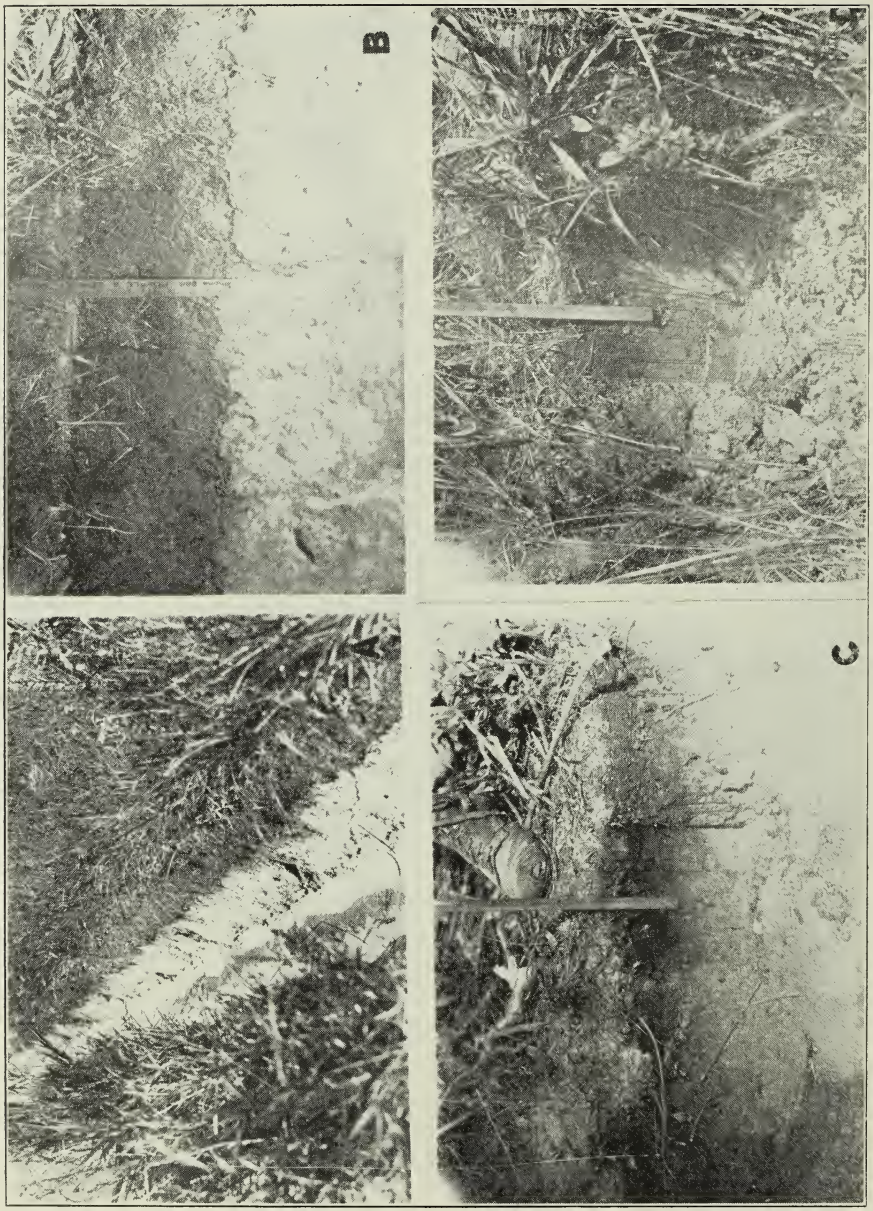


Plate 14. Soil humus conditions. A. Road ditch section near transect C showing humus thickness. B. Face view of preceding; soil humus to depth of 32 cm. C. Soil humus of upland bay (Ilex-Myrica), 12 cm. thick. D. Soil humus of juvenile grass-sedge bog 13 cm. thick.

Plate 15. A. Soil humus at transect E, 11 cm. B. Soil humus of grass sedge bog, older than that shown in pl. 14 (D), 17 cm. C. Sod transplant from station 2, (Panicum consocies) to station 1, (Campulosus consocies). D. Same as preceding, 13 months later showing marked reduction under the longer hydroperiods.

HUMUS ACCUMULATION RELATIONS

Major Factors	Humus in Mineral Soil	Humus on Mineral Soil (muck or peat)
Surface water hydroperiods long and frequent		
Lowland—swamps Upland—very broad bays or sphagnum-shrub bogs	Thin to medium thickness, 5-25 cm.	Thin to thick, 5-200+cm.
Soil water hydroperiods long and frequent		
Level uplands only Small to medium broad bays or shrub bogs No fire	Thin to medium, 5-20 cm.	Thin, 1-10 cm.
Grass-sedge bog Fire	Thin to thick, 10-40 cm.	None
Soil water hydroperiods moderately long and frequent		
Moderately drained bays No fire	Thin to medium, 5-15 cm.	Thin, 1-5 cm.
Moderately drained meadow communities Fire	Thin to medium, 5-20 cm.	None
Soil water hydroperiod only short and infrequent		
Well-drained forest sites, slopes No fire	Thin, 3-10 cm.	Thin, 1-5 cm.
Well-drained meadow Fire	Thin, 3-10 cm.	None

Despite the presence of the black humus in the mid-bog soil, the water which flows directly from this soil is perfectly clear; no dark humic materials are washed out. This of course is in striking contrast to the situation in coarser sandy soils where the drainage waters are always of a dark coffee-color due to the leaching of the humic compounds.

The experiment was tried of filtering some of this dark water through a small amount of typical mid-bog soil. It came out perfectly clear. The explanation of this phenomenon is unquestionably related to the process of adsorption. So fine is the bog soil and so large is the surface exposed, that all such pigment molecules or aggregates are persistently held by the particles.

H-ion. Using the Wherry method with distilled water the following data were obtained:

	Surface	12 cm.	40 cm.
Station 1	4.4	4.6	5.0
Station 2	4.6	4.8	5.0
Station 3	5.0	5.2	5.6
Station 4	4.6	4.6	5.0
Station 5	4.4	4.6	4.8
Station 6	4.6	4.6	5.0
Station 7	4.6	4.6	4.9
Station 8	4.6	4.6	5.0
Station 9	4.6	4.8	5.4
Station 10	4.8	5.0	5.4

The water from the deeper soil taken from wells shows a hydrogen ion concentration of 7.0-7-2.

From the above data it will be seen that the acidities of the Campulosus and Panicum consocies range close to 4.6, no marked change being observed until the well drained Quercus-Hicoria or Andropogon areas are reached.

Though not evident in a striking manner, there nevertheless was always found a slightly greater acidity at the surface than at the 12 cm. depth and further, the well aerated ant hills also showed a small shift toward the acid side.

Total carbon and organic matter. The total carbon content for three stations (12 cm. depth) was investigated. The results multiplied by the factor 1.724 gives the total organic matter in the soil.

	Total Carbon %	*Organic Matter %*
Station 1, Campulosus consocies	3.124	5.385
Station 2, Panicum consocies	3.255	5.511
Station 11, Andropogon consocies	2.108	3.634

It is interesting to note the similarity in the results of the first two items which throw this factor out as a controlling element in the distribution of the two bog consocies.

Kerr's analysis (6) of the mid-bog soil gave 4.88% organic matter, so the percentage of organic matter associated with the sand apparently varies around 5%.

Oxygen. Flooded soil. During a hydroperiod, an oxygen content test (Winkler method) was made of the mid-bog water, the water being drawn from an open crayfish hole at the depth of 12 cm. A mere trace was found in the three tests made, viz.: .3 ppm., .4 ppm., .3 ppm. The same water after shaking and introducing atmospheric oxygen freely, gave 7 ppm., of oxygen.

Non-flooded soil. The following test (Goldsmith-Haldane aerometer) was made under conditions of an extremely low water table, the result of some 35 days of drought. Under these conditions the soil air was the equivalent of atmospheric air. The mid-bog in three tests gave the following percentages of oxygen: 20.46%, 20.45%, 20.75%.

Of especial interest in connection with the oxygen problem is the presence of *Drosera rotundifolia* and *Utricularia subulata* on the surface of the intertussock areas. Rooted as these small plants are in the surface centimeter of soil, the hydroperiod for them is much shorter and the surface water also would be better oxygenated.

Total nitrogen. The total nitrogen of the open bog soil is definitely higher than that of the marginal soil (Panicum consocies). Further, the central bog soil gave about four times as much total nitrogen as that found in a cultivated field on a neighboring slope.

Nitrate content. There are no nitrates in the central bog and but a mere trace in the marginal zone.

Ammonia content. The bog soil regularly contains ammonia. Considering the very low nitrate content mentioned above, it would seem that the bog plants are getting their nitrogen as ammonia.

Type and number of microorganisms. The bacterial content of the bog is very low which was naturally to be expected in this type of soil. Actinomycetes are present but under the condition of low oxygen induced by the frequent long hydroperiods, they are not able to carry out their function of lignin decomposition, hence the relatively rapid accumulation of humus.

Under aeration and liming, the soil bacterial flora makes a remarkable increase.

PHYTOMETER STUDIES

Supplementing the field observational studies of species distribution, experiments were initiated in three directions. (1) Field transplants. (2) corn, sunflower and bean from seeds on field areas. (3) the same in pots in the greenhouse.

Field transplants. So compact are the bog and related soils that sod transplants are placed with much ease. The following table summarizes the work of this character accomplished:

SOD TRANSPLANTS	RESULTS 1 YEAR
Panicum consocies (station 2) to Campulosus consocies (station 1).	Definite reduction and elimination of all typical Panicum consocies elements (pl. 15, C-D).
Andropogon virginicus from old field to Campulosus consocies.	Eliminated.
Aristida stricta from sand ridge area 6 mi. distant to Campulosus consocies.	Reduced but not eliminated.

Transplants of the bog sod were made to other nearby habitats with results in agreement with expectations. In the open transition region (Panicum) no marked change was evident. In the forest only the reduction and modification due to shade occurred.

Various shrubs and small trees placed in the bog at station 1, uniformly showed striking reduction of internode length.

Crop plant phytometers. Short hydroperiod plants (corn, sunflower, bean) showed strong repression in both bog and transition habitats, but more in the former. The bean plants exhibited by their conformation of root systems, the influence of the different hydroperiod. At station 2 the plants were deep rooted while at station 1 they were shallow rooted. Nodules were observed on the roots of the latter while none occurred on those of the former, a fact to be correlated with the absence of legumes on the bog.

After planting seeds of cotton, rye, oats, sunflower and corn, seedlings appeared but all were killed within a month. Corn plots made on the ditch margin (station 4) amid typical bog vegetation, where the hydroperiod was very short, still showed a marked degree of repression but were not killed. This indicates that the earlier longer hydroperiods have developed a condition in the soil which acts repressively even after the hydroperiod is shortened. For a full discussion of this significant point, see section under "Lag effect of bog condition".

Pot experiments. Using sub-irrigation with the water level 12 cm. below the surface of the soil, it was found that root penetration was very severely checked due to the high water content of the soil. The roots in all instances were found massed against the aerated sides of the clay pots, indicating the significant oxygen relation.

Lag effect of bog soil condition. One very important fact comes out from the simple observation of the bog vegetation along the roadside ditches. Even though these ditches have been in for six or eight years, no change in vegetation has occurred; the familiar typical Campulosus complex holds on up to the very edge of the ditch. Immediately across these ditches on the ridge of earth thrown up along the roadside, is a host of the Andropogon consocies, species which are entirely unable to establish themselves on the well drained ditch border soil (pl. 16, A). This lag effect, however, is not permanent, for in the case of the deeper railroad ditches (pl. 17, B) which have been in for 75 years, the bog conditions have become modified so that for a distance of 50-60 feet back from the ditch, one may observe the presence of Panicum consocies elements.

The cause of this lag effect cannot be explained by a secondary flooding effect due to the elevation of free water by capillary activity, since the porosity studies show this of little significance above 15 or 20 cm., and the bog ditch of the photograph is 65 cm. deep. One of the possible factors operating in the holdover of essential bog conditions is high acidity, pH 4.6, acting indirectly either by developing soluble aluminum or iron, resulting in toxicity for the non-bog plants, or by checking bacterial growth (nitrifiers) and thus making it impossible for plants not using ammonia to become established. There further remains the hypothesis of organic toxins but in our experiment using leachings from this soil, no inhibition of growth was produced.

Once this soil is brought into the bog condition through the basic factor of flooding with the concomitant lowering of the soil oxygen, a sequence of factors ensues which persists for an extended period of time after the original cause is removed.

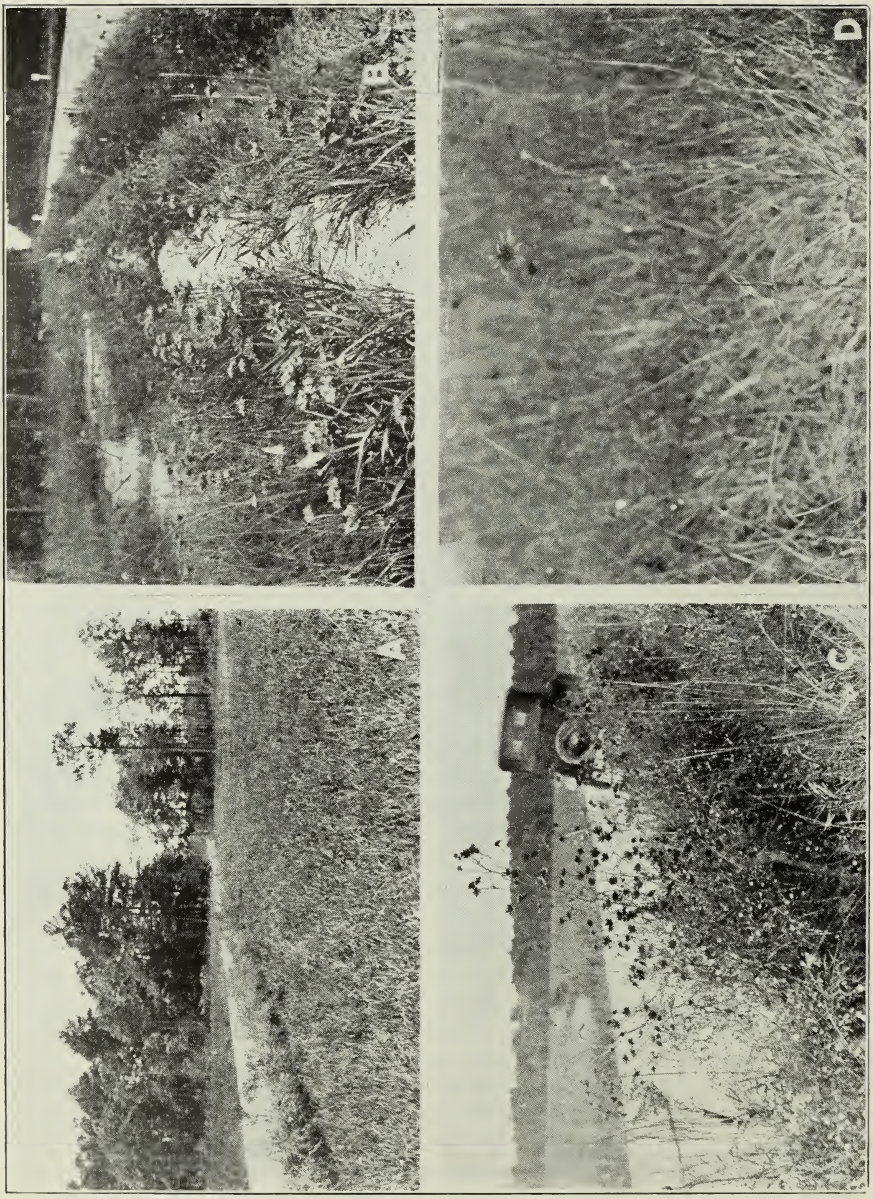


Plate 16. Response on ditch banks. A. Bank (ridge) between ditch and road near transect C. Note contrast in vegetation of bog edge and that of bank. B. Gyrotheca tinctoria responding to conditions of a ditch bank in Columbus County. Response of Helianthus angustifolius to bank conditions. Contrast with next. Helianthus angustifolius on bog.

Plate 17. Response of Arundinaria on ditch bank at east end of bog. B. Vegetational response to influence of railroad ditches which traverse the center of the bog. C. Bare area on bog after exposure of 1 year and 3 months. D. Fire repressed specimen of Nyssa biflora over 50 years old.

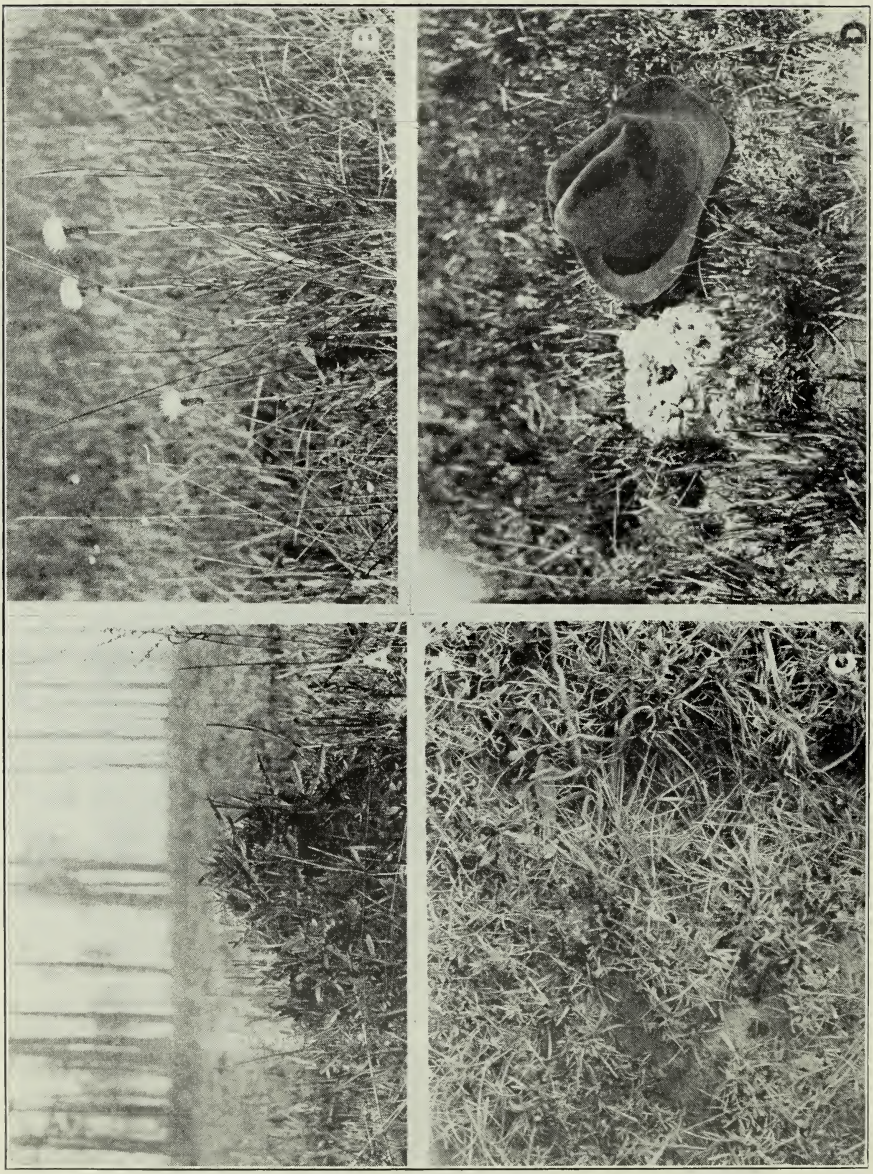


Plate 18. A. Carduus LeContei, the indicator of ant hills on the bog; spring aspect. B. The preceding in summer aspect. C. Surface of bog showing bare intertussock areas which commonly lead to a crayfish hole. D. A crayfish chimney.

There is evidence that this factor complex still operates not only after drainage, but also after cultivation.

FIRE RELATIONS

Of prime importance is fire (pl. 19, A-D, pl. 20, A-B) in determining whether or not an upland area in the flat sandy lands shall be dominated by woody plants (Ilex-Myrica-Cyrilla associes) or by herbaceous perennials (Campulosus-Panicum associes). In this succinct statement the story of fire on the sandy flat lands is told. On the muck and peat areas in sharp contrast to the situation on the mineral soils, there is no transformation to the herbaceous complex; the shrub-bog associes still persists in the face of annual or frequent fires.

A brief analysis of the fire element may be given here. The following are some of the principal subsidiary factors controlling the intensity of the fire.

Living vegetation
- Diversity
- Type
- Water content
- Concentration

Vegetation debris
- Water content, or relative dryness
- Concentration

Climatic elements
- Direction of wind
- Rate of wind movement
- Precipitation
- Dew.

In addition to intensity, fire frequency is also of major importance. The agents controlling frequency are two in number, man and lightning, with the former alone important in the area under consideration.

SUCCESSION: THE GRASS-SEDGE BOG SERE

The story of plant succession on the area studied began with the emergence of this area from the sea, when the Wicomico Terrace was formed. During the time that the bog area stood a few feet above the ocean level, after the upward movement which gave it origin, the vegetation dominating throughout most of that period was probably that of Ilex-Myrica-Cyrilla associes which community was still prominently represented well out on the bog margin, up to recent time. At the northeast end (station 19) where fires have been frequent, this community is still present though it has been temporarily reduced by burning.

There is no evidence whatever that the area ever had average hydroperiod maxima long enough to support Taxodium, for where this has occurred, partially buried logs are always evident. *Nyssa biflora*, on the other hand, a swamp forest element which holds on under shorter hydroperiod conditions of stream heads and poorly drained uplands, has always

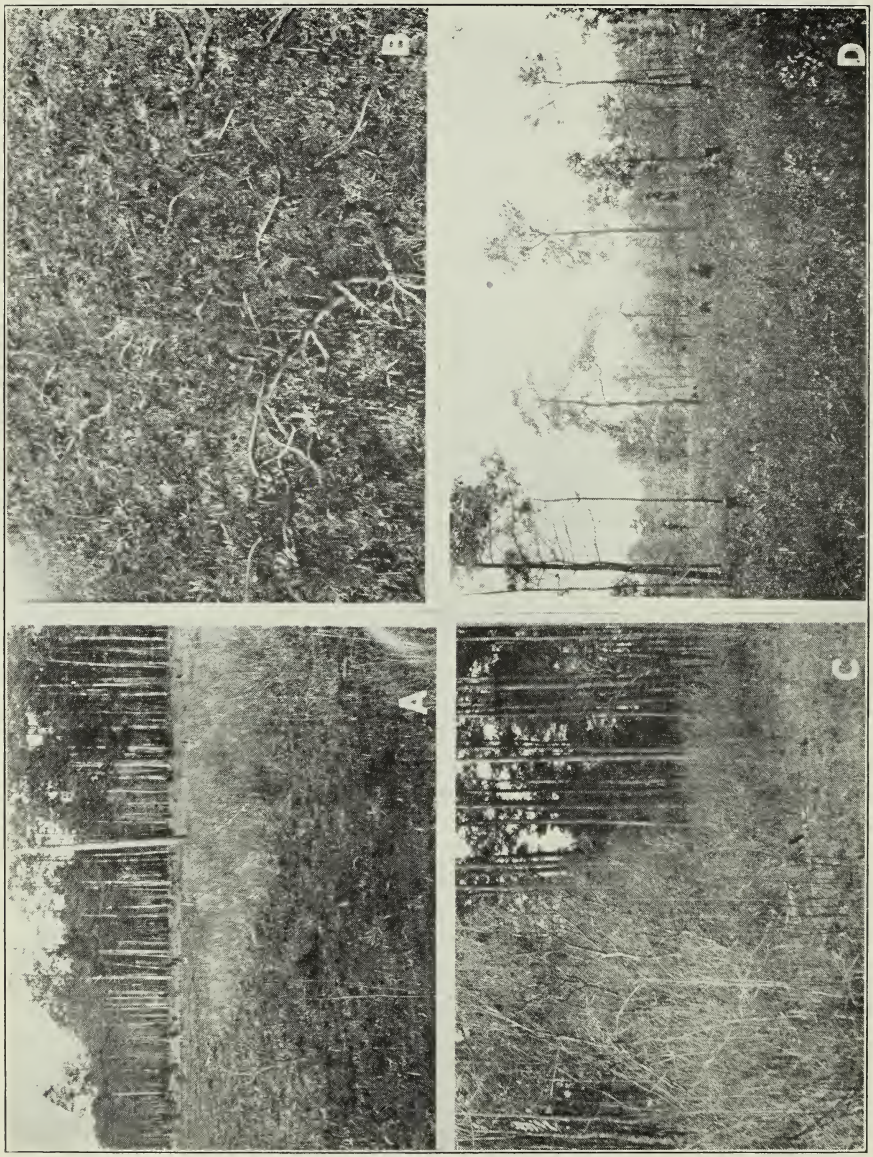


Plate 19. Response to fire. A. Open bog, contrast of burned and unburned areas. Fire extinguished by rain. B. Surface stubble after fire. Note resistance to burning made by the stems of *Lycopodium abpecuroides*. C. Fire tension zone at stream head near station 8. Cyrilla in contact with grass-sedge community. D. Region of infrequent fire east end of bog showing survival of oaks.

been prominent, though still a subdominant. As heretofore described, fire-repressed cane is still today prominent in the streamheads terminating in the bog.

Doubtless in former times when fires were very infrequent, the area may have carried a layer of muck on the surface, for a thin section of this material may be seen today in the region of station 19.

We may thus regard the Sphagnum-Cyrilla associes as the pioneer of the site. With it as subdominants probably occurred the following typical bay elements: *Acer caroliniana, Ilex glabra, I. lucida, Magnolia virginiana, Myrica cerifera, Anchistea Virginica, Pieris nitida, Pinus serotina, Smilax laurifolia, Viburnum cassinoides.*

Two seres may now ensue (fig. 10) related to the absence or presence of fire. Without fire the only process making possible change is that of degradation, in which slope with its concomitant shortening of the hydroperiod is introduced. This will result in swinging the wet bay (Sphagnum-Cyrilla) to dry bay (Ilex-Myrica), followed by the oak-hickory forest leading to the climax beech-maple. So frequent and destructive is fire in the region under discussion, since the area has been occupied by white men that the preceding sere is of theoretical interest only.

The actual story of the sere here, is as follows: With the advent of fire, but still infrequent ones, the typical shrub (Cyrilla) consocies changed to the cane (Arundinaria) consocies. This was probably confined to the more central portion of the area. A number of the old inhabitants tell of the cane "higher than a man on horseback". This same seral movement may be observed in striking manner today in any of the large "bays" or "pocosins" by which names Sphagnum-Cyrilla associes is known locally. The grass-sedge community has mastered the area. Under the annual fires this community occupying the central area has become fully matured and stabilized. It constitutes a striking example of a fire-maintained subclimax.

Further reference again to the diagram of the bog successions will show two divergent possibilities with regard to the occurrence of degradation or no degradation. In the case of the latter, the grass-sedge subclimax under the annual fires will persist indefinitely. In the case of the former the seral movement is readily discovered by examining the various portions of the streamhead already pressing slowly in on the area.

Figure 11 is a diagram of the physiographic zonation introduced by headward erosion (degradation). This diagram is based upon the streamhead and lower basin of the stream, a branch of Horse Creek, in which our transects were located. Hence our technical studies here bear most intimately upon this phase of seral change.

A glance at this figure will show two divergent subseres from the same bog community. The area at the end which is destined to become the stream course will obviously have a different history than that at the side.

With regard to the first, attention must be called to the presence in the open area immediately surrounding the Cyrilla border of the

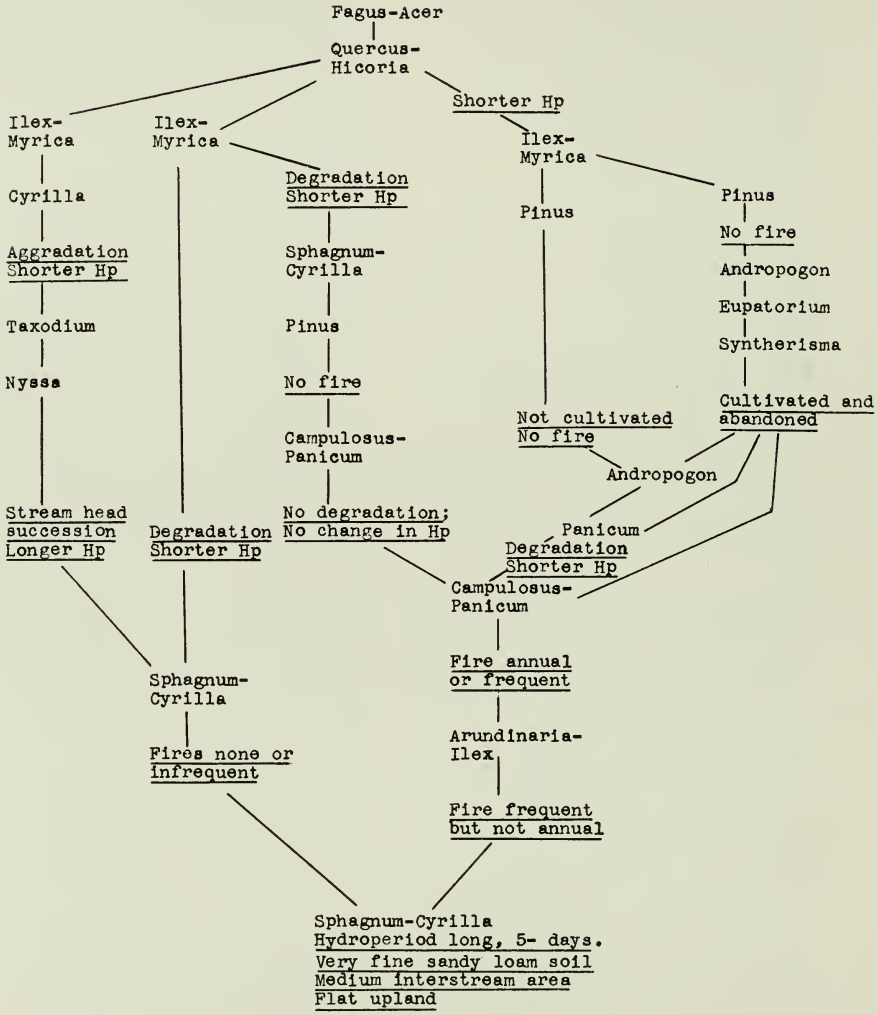


Fig. 10 Outline of the Campulosus and related seres.

stream head, of a number of shallow marsh species that occur here and only here in the zone labeled Ludwigia (L. hirtella), one of the characteristic subdominants. Others are *Asclepias rubra, Carex crinita, Lysimachia Loomisii, Melanthium dispersum.* They simply indicate the marsh-like character of this portion of the transitional Panicum community.

Of the seral movement of the terminal area in the diagram, or its equivalent, the space occupied by the number "7" on the map, the marsh-like transitional area changes rather sharply to the Cyrilla consocies of the Ilex-Myrica-Cyrilla associes, which latter consocies contains *Nyssa biflora* and *Pinus taeda* to a prominent degree.

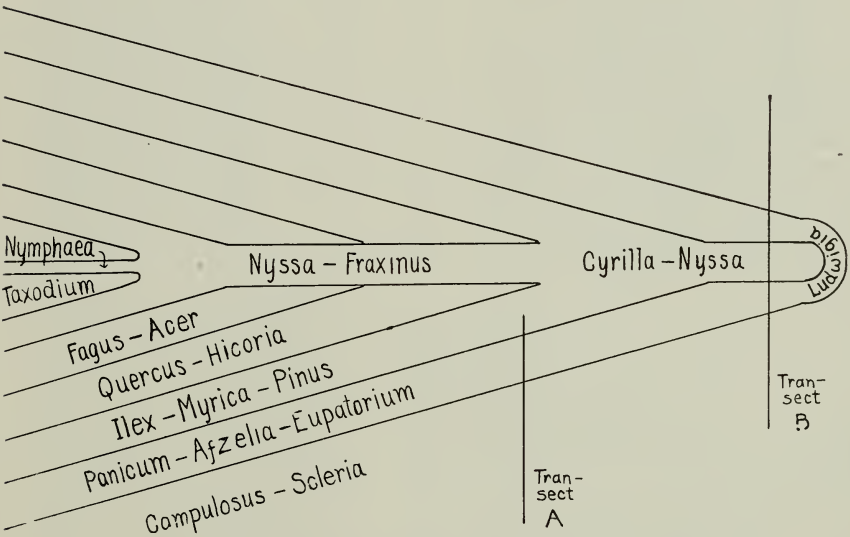


Fig. 11. Diagram of stream head showing relation of the communities.

Eventually as indicated in the present stream basins, the "wet bay" would become a river swamp carrying the familiar Taxodium-Nyssa swamp forest with aquatic species (*Nymphaea sagittaefolia* and others) in the open water.

Following the sequence of events at a lateral station, or its equivalent at station 1 of the map, we may read the outlines of the seral story by a glance at fig. 11.

The intensive studies were made in relation to the initial stages, viz.: the transition from pure bog through the open Panicum community into the Ilex-Pinus zone, and ending with the Quercus-Hicoria associes. The quantitative data presented heretofore may now be correlated with communities of the erosional sere under annual fire.

Plate 20. A. Reduction of Pinus serotina under fire, east end of bog near station 16. B. Shrub bog and grass-sedge bog; influence of highway in fire control. C. Twenty-five year old stand of Pinus serotina, a fire succession near station 19. D. Same as preceding showing contact with a 35 year old stand in left one-third of picture.

Plate 21. Pine succession in absence of fire. A. Pinus taeda, 10 years. B. Pinus taeda, 20 years. C. Near view of preceding showing development of bay species. D. Pinus taeda, 35 years, near "Woodstock Savannah", Beaufort County.

CAMPULOSUS AND PANICUM CONSOCIES

The difference in vegetational composition of the communities has been presented earlier.

Statements of habitat factor contrasts have also been presented and need but be summarized and discussed here.

CAMPULOSUS	PANICUM
No slope	Slope, or if not, better drainage.
Hydroperiod longer	Hydroperiod shorter
Soil with humus layer thicker	Soil with humus layer thinner
Soil acidity slightly greater	Soil acidity slightly less
Soil O less	Soil O greater
Total N greater	Total N less
No nitrates	Trace of nitrates

In fig. 5 the correlation of certain of these factors with the vegetation has been graphically shown. The numbers in the figure refer to the stake positions (50 ft. intervals) marking wells for measurement of water table, of transect A. As may be noted in the two graphs immediately below those dealing with the fall of the water table, the relief involved to the point (stake 11) is from 35 cm. in 500 feet. To the bottom of the stream basin to which this slope leads some 600 feet away from stake 11, is only 110 cm. This relief together with soil texture constitute the basic factors under the local rainfall frequency controlling the differential hydroperiods. While at stake 11 the water falls 10 cm. the first day, at stake 1 (having taken a day to rise to the surface) it takes 5 days to bring about the same amount of recession. In exact correlation with these data is that of the distribution of the ecads shown below. Also note the correlation with humus depth; the long hydroperiod favoring humus accumulation. This graph does not include the woody plant (Ilex-Myrica) consocies immediately adjoining it. *Pogonia ophioglossoides* is introduced with the graph as a bog species which is kept out of the more favorable hydroperiod region by competition. It is a low plant and the more luxuriant vegetation of the marginal zone prevents its appearance. *P. divaricata*, it may be pointed out, is a much taller and more robust species but even it is not a frequent plant in the transitional zone.

It will now be of interest to refer to fig. 6, which is the graphic delineation of the water table movement along transect B. Here the total relief is much less than that of the slope involved at A, being but 46 cm. Yet this is sufficient to induce a contrast in hydroperiod with a resultant response in the vegetation. As before, the numbers at the top refer to the stakes at 50 ft. intervals. Three consocies are included here, Campulosus, Panicum, and Cyrilla.

To meet the requirement of space, ordinate and abscissa units had to be used which forced an artificial appearance of the graph in the central region, where the water table appears to rise above the general level when it actually was but rising in the swamp.

On the left here, the same transition is found from bog to shorter hydroperiod species which was shown in the preceding graph of transect A. Here, however, it took slightly over two days at stake 8 for the

water table to drop 10 cm., while in the bog at stake 1, it took 6½ days. To be correlated with the longer hydroperiod of this transition region, is the presence at this region of such marsh-like elements as *Ludwigia hirtella.*

The very long hydroperiod of the swamp bottom is brought out, 6¼ days with water above the 10 cm. level, during 5 days of which it was above the ground surface level.

The anomalous rapid fall at stake 15 is probably related to contact with some subterranean outlet leading down the stream basin.

Of especial interest is the shorter hydroperiod of stake 23, located on the level land well out in the interstream area between the stream head and the main basin of the parent stream, into which latter the water moved by lateral movement through the soil. Though the 10 cm. hydroperiod following heavy rains was slightly more than three days (probably a good average after the area is flooded) the typical transitional ecads of the preceding transect occur in abundance.

Recent observations made during the summer of 1927 are of much interest. Due to low precipitation for two growing seasons, the flooding factor has not been operative on the bog proper with the result that *Andropogon scoparius*, a prominent grass of the Panicum consocies made a mass entry on the area. The plants occupied the bare intertussock areas. Ecesis, however, did not occur on certain restricted areas which had not been burned. The shade factor of the old vegetation mat unquestionably prevented establishment. The occupation of the bog by Andropogon will cease when the normal hydroperiods are again present.

PANICUM AND ANDROPOGON CONSOCIES

Since the Andropogon consocies may only occur on the bog area where an open region is located near and at the side of a main stream basin in this particular soil region, its prevalence is highly restricted. With this consocies is associated the shortest hydroperiod and in other ways the soil approaches the average soil of well drained uplands. The hydroperiods (though not shown graphically), seldom extend beyond a day, being always definitely shorter than that of the Panicum consocies.

PANICUM AND ILEX CONSOCIES

The composition of the Panicum consocies has been presented. The Ilex consocies of the Ilex-Myrica-Cyrilla associes into which the Panicum community passes sharply, is composed of the following: *Ilex glabra, Acer caroliniana, Magnolia virginiana, Liquidambar styraciflua, Myrica cerifera, Gelsemium sempervirens, Pinus taeda, Gaylussacia frondosa, Aronia arbutifolia.* A number of bog and transition herbaceous elements are found associated in the local openings of the above community.

Throughout a large part of the length of the environing woodland there exists a fire ecotone or tension zone represented by the transition from Panicum to Ilex consocies (pl. 10, A, C). On the slightly steeper slope beyond the Panicum zone, the shorter hydroperiod favors the growth of the upland bay vegetation to such a degree that it is able to maintain itself against the frequent fires. By means of the shade factor

the species of the Andropogon consocies are prevented from entering, which they would promptly do, were the woody plants removed by cutting. Striking examples of this latter phenomenon may be seen in a number of marginal areas.

PANICUM AND CYRILLA CONSOCIES

At the stream, in striking contrast to the above, the Panicum consocies is in direct contact with the Cyrilla consocies of the Ilex-Myrica-Cyrilla associes. This contact is another fire ecotone. The upper swamp habitat and vegetation is of such character that the advent of fire cannot produce a change in vegetation; it merely sets back the bay elements temporarily, from which condition they are quickly restored during the following season.

Along the fire ecotine downstream from the streamhead, a gradual change from the Cyrilla to the Ilex consocies is observed, the Panicum consocies being in contact with both.

ILEX AND QUERCUS CONSOCIES

The transition here again is related to slope with its concomitant change in hydroperiod and constitutes a major movement in the erosion sere.

NON-PYRIC SUBSERE

So extensive are the areas exposed to fire that it is difficult to locate areas which having once been in the grass-sedge bog condition have subsequently been protected from fire. In the environs of the bog under discussion only two such areas were located which from all that could be learned about them, indicated them to be genuine non-pyric communities.

The youngest exhibited a close stand of *P. taeda*, 10 years of age, with 50 to 60 trees per 10 meter quadrat (pl. 21, A). Thus the pines completely dominated the area. As very subordinate species the following were noted: *Ilex glabra*, *Gaylussacia dumosa*, *Liquidambar styraciflua*, *Myrica cerifera*, *Silphium pinnatifidum*. In the oldest area were found but 15 to 25 pines to the 10 meter quadrat but there was evidence of some cutting here (pl. 21, B). The following bay elements were found playing a much more prominent role than in the preceding: *Ilex glabra*, *Liquidambar styraciflua*, *Acer caroliniana*, *Clethra alnifolia*, *Cyrilla racemiflora*, *Smilax laurifolia*.

On the margin of the non-cultivated Woodstock bog area (Beaufort county) a fine 35 year *P. taeda* stand was noted (pl. 21, D). It still maintained complete dominance over the bay vegetation.

The outline of the non-pyric subsere is thus clear. The area is speedily taken by the *P. taeda* consocies to be held by it for an extended period or until cutting, fire or natural thinning so open it up as to make possible the dominance and transfer of control to the Ilex-Myrica-Cyrilla associes. The early mastery of the area by *P. taeda* is readily understood when one may observe any season the innumerable pine seedlings springing up, well out on the open bog area where they are soon eliminated by the next fire.

OLD FIELD SUBSERE

In a few places on the bog margin fields have been tilled and abandoned. A brief statement of this subsere will, however, be in order. *Syntherisma sanguinale* is dominant the first year. During the second and third years, the tall weeds come in: *Eupatorium capillifolium, E. hyssopifolium, Aster sp., Erigeron canadense.* Following rapidly various species of Andropogon (Virginicus, Elliottii) and others take it over until the pines enter, provided fire does not reach them. Based upon evidence furnished by an experimental plot abandoned 40 years ago, the old field area will gradually become mastered by the grass-sedge bog complex, provided annual fires occur.

CULTIGEN EXPERIMENT

Having early discovered that this flat upland area was bog in nature, it occurred to the authors to test cranberries on it. In April, about 100 plants were placed in each of two meter plots prepared with mattock and spade. Around one was built a low embankment 10 cm. high. Despite the fact of an extraordinarily dry season with the water table never reaching the surface, the plants grew, flowered, and set fruit by August 10th. Under the condition of the dry season the banked plot showed about twice the production of the unbanked.

It should be stated that such a preliminary experiment does not indicate that cranberries may be grown commercially on this type of bog.

DISCUSSION

In the foregoing portion of this paper an analysis has been made of all the significant factors that have operated to bring a particular southern grass-sedge upland bog into being, and further an outline of possible future changes has been presented.

As heretofore stated, the basic controlling factors in the seral movement of the bog vegetation are those related to topography, soil and fire. The interaction and relative importance of these have been discussed. However, it will not be amiss here to point out that of these three the vast complexity of the subsidiary factors included under "soil factor", though no more important than topography and fire, constitute the major problem of such a study as this one.

A complete analysis and proper evaluation of the multiplicity of soil factors is impossible with our present knowledge and technique. In the present study, however, these factors assume a particular relation which has made possible some advance. The complex of bog soil conditions proper is the sequel of the original long hydroperiod with its concomitant low oxygen factor. We have worked out a method of quantitatively dealing with this factor and have been able to directly correlate the facts of vegetational distribution with these data. From these observations, definite conceptions have been obtained with regard to the working of this basic soil factor in the seral movement, so that an outline of the particular bog sere as well as all other inland seres of the coastal plain has been made possible.

Before entering upon a more detailed discussion of the significant edaphic factors some discussion of the minor role of climatic factors must be presented.

The atmometer data shows a rapid vertical increase in the evaporating power of the air at the two bog stations. The mass of the foliage occupies the lower stratum of air which with its lower evaporation constitutes the more favorable habitat. Nevertheless the plants show marked xeromorphy which may or may not indicate xerophytism. As indicated previously there is no correlation between the evaporation data and species distribution; only a differential response of the vegetation with regard to size was evident.

One of the outstanding results of the investigation has been the demonstration on a quantitative basis of the factors concerned in the delicate control that obtains in areas of low relief and in the matter of vegetational distribution. We have been able to definitely differentiate for the first time, two herbaceous bog communities on the basis of the hydroperiod which is controlled for the most part by the topography. In our transect B, the relief was but one and a half feet, yet this induced the differentiation of three distinct consocies, the Campulosus, Panicum, and Cyrilla communities.

In still another manner is the control by slight relief expressed, viz.: in connection with the phenomena related to ant hills. These low conical structures are never completely covered with water, are of course well aerated and on them the Panicum consocies plant *Carduus LeContei* is uniformly represented. Their acidity is just as high if not a little higher than that of the bog soil indicating very definitely the lack of correlation between acidity and the distribution of this vegetation.

With regard to crayfish holes the evidence goes to show that they have no influence on the vegetation. There is no perceptible difference between areas with and without them.

Of major importance is the matter of soil texture since this is related to the control of the hydroperiod. Our data show in most striking manner the practical import of the experimental tables dealing with water movement through soils. In soils underlaid with an impervious non-draining subsoil as these bog areas are, the rate of downward and lateral movement becomes a very important factor in determining the hydroperiod. As will be pointed out later the soil texture assumes a major role in drainage projects on the fine sandy loams.

Most intimately related to texture is the factor of porosity. A glance at fig. 9 shows the break in the curve not far above the water table or around eight inches. In a soil like that of the Woodstock area, this break would be measurably closer to the water table. We thus here have evidence that the finer the soil the longer the hydroperiod. As will be shown later these facts are of immense importance from an agricultural point of view.

The correlation figures, 5 and 8, are self explanatory. In the presentation of contrasting data of acidity and humus layer thickness, we do not imply in any sense that these are causal factors in control of the vegetation. They are not. Both are effects of the relatively long hydroperiods. In the case of the humus infiltrated layer, this is thicker as would be expected where the hydroperiods are longest and the least

opportunity is offered the actinomycetes and bacteria to carry out the disintegration of soil organic matter. Thus the thickness of these humus layers is of much interest in interpreting the past, present and future of both vegetation and habitat.

Probably the best expression of the hydroperiod data is that of the rate of fall developed by plotting the daily increments against days (fig. 8). The significant portions of these graphs are the parts designating the early days since at this time the water table is in the upper layers of soil, where it may affect the vegetation. A comparison of these graphs with the data of habitat and vegetation at the respective stations will confirm all that has been previously brought out concerning the significance of the index hydroperiod in ecological studies of soils with higher water table.

The humus content of the bog soil should be mentioned in connection with its significance in producing a high water holding capacity, viz.: about 65%. Even though the soil shows but 5½% organic matter this material distributed in the fine interstices strongly contributes to the high water holding capacity, which in turn makes its contribution to the maintenance of the bog soil condition.

All of our data definitely indicate no correlation of the H-ion factor with the plant distribution.

The oxygen relation is unquestionably of much importance. The almost complete lack of oxygen in water taken near the surface from a crayfish hole indicated the relatively small amount of oxygen normally contained in such exposed water (6-8 ppm.) to be rapidly taken up by the soil organisms, more rapidly than diffusion from the air could keep up the potential content. An extremely low oxygen content is a regular occurrence under the flooded condition. The presence of aerifierous tissue in the subterranean parts of the bog plants is to be correlated with this factor. But as has been clearly demonstrated in the discussion of the lag effect of the bog condition, low oxygen is probably but the primary factor producing in turn a complex of other factors which may later independently maintain the bog for an extended period after the oxygen is free to enter the soil at all times.

The nitrogen situation is similar to that in other bogs, low or no nitrates, high total N (mostly unavailable), and some ammonia being characteristic. Slight differences were found in these conditions between the soils of the Campulosus and Panicum consocies areas, but they were not sufficient in amount to indicate control.

Of the factors which have appeared as a consequence of flooding, much quantitative data are offered. The evaluation of these factors and their interaction is of course at this time impossible. That they may continue to function long after the primary factor producing them has been removed, is a matter of much interest and soils in which this situation occurs (ditch border zone) should prove especially valuable for future work in the attempt to unravel this complex of causal elements.

The importance of fire has already been brought out in connection with succession. The relative rapidity with which it produces its results, stands in strong contrast to the extreme slowness with which erosion produces its effects in controlling the seres.

PRACTICAL APPLICATIONS

A number of important practical applications may be made of the data worked out in this study.

1. **Use of native vegetation to indicate drainage conditions.** The remarkable degree to which the native herbaceous vegetation responds to slight changes of drainage makes the use of plant indicators highly valuable, when it comes to choice of land for various agricultural purposes.

Areas carrying only the characteristic bog flora (Campulosus consocies) should be avoided. The cost of draining them would be excessive as our ditch transect hydroperiod data show. At a point 50 ft. from the ditch it took the water table 5 days to reach the 1 ft. level. In the neighboring flat Panicum area, it took about half that time.

With regard to areas carrying the characteristic Panicum consocies species, there can be no doubt of their use in agriculture. These will, however, naturally suffer in wet years. Many of the present extensive trucking developments are on areas of this type.

It should be recognized, however, that the first choice of land for cultivation in the general region would be the white oak slopes. As indicated on the general map, the gentle slopes everywhere from the upland bog to the swamp carry the oak-hickory forest, which together with the beech-maple forest indicates the best land in the entire region. The natural drainage of such areas is always good and little need be done to supplement it. It has been repeatedly observed that these "oak flats" are left intact while other less desirable uplands are used for cultivation.

2. **Use of hydroperiod data.** Hydroperiod information may be of value in certain ways. (a) It may furnish a check on conclusions drawn from observation of the native vegetation. (b) It will act as a guide in determining the number of ditches necessary per unit area. (c) It will prove of value in checking drainage conditions in fields already established.

A study of our graphs for the type conditions studied will furnish a basis for comparison of data from similar areas. These show that the 10-20 cm. hydroperiods (the significant ones from the standpoint of flooding injury) are twice as long on the Campulosus areas as on the Panicum ones. For the former the 20 cm. period averages around 6 days and for the latter, 3 days. Desirable land should in all instances, it is believed, show a 20 cm. hydroperiod of 3 days or under. Such areas when ditched will quickly bring that time down to the safe figure for crop production, of a day or less. Under these conditions the chance of prolonged frequent rains extending the hydroperiod to the danger point is much reduced.

Attention should here again be called to the role soil structure plays in controlling the hydroperiod. A remarkably small shift in the figures relating to the mechanical analysis may account for a marked increase in movement of water laterally, making possible a shorter hydroperiod. In this lies the explanation of the fact that the Woodstock Savannah in Beaufort County could be profitably cultivated while that near Burgaw cannot be.

It may be here pointed out that had the information relative to the use of plant indicators and hydroperiods herein presented been available earlier, a large number of agricultural failures would have been prevented, prominent among which was a 30 family colonization settlement.

3. **Soil improvement through use of acid phosphate.** As previously described, this soil does not improve immediately with drainage; a certain unknown factor complex holds on, permitting no change in the vegetation. Following a suggestion of L. G. Willis, soil chemist, it was found, however, that a heavy application of acid phosphate definitely improved the soil as indicated by corn. In a bean field on this soil type where haystacks had been burned, the bean rows widened to almost twice their diameter through thrifty growth induced by some effect the ash had on the soil. This observation also indicates that in this field which had been under cultivation for 5 years, this same lag effect was operating which is such a striking phenomenon on the border of the bog ditch. As heretofore indicated this situation constitutes a major problem in itself and cannot be pursued further here.

4. **Indirect deleterious effects of fire on soil.** From successional studies nothing is more apparent than that as the vegetation changes from the shrub bog to the grass-sedge bog, the humus layer or bog soil, grows thicker. And as has just been shown, this is tending toward more and more unproductive land. Hence, in these facts we have another strong argument for protecting the shrub bog areas from fire, if these areas are later to be brought into cultivation. Further, if the areas now changed are protected and the normal pine-bay succession ensues there will be slow but certain improvement of the land for agricultural purposes. This is of significance chiefly in regard to areas carrying the Panicum consocies, which are open to economical drainage.

5. **Reforestation.** Since the Campulosus type of area is of little or no value in the production of ordinary crops, it may be recommended that it be planted with loblolly and long-leaf pine. If left to nature they will under present conditions come up in loblolly rather than long-leaf, the more valuable tree. These pines will come in thickly so that artificial thinning must be resorted to if the stand is to be properly developed for lumber.

In an earlier day most of such areas as the one under discussion carried the worthless pocosin pine, but due to the general improvement of drainage conditions with the opening up of the country, it is now possible to use these fire opened areas for the more valuable trees. These gains, however, are not now held because of the frequency of fire, giving the trees no chance to become established.

6. **Possible use of special crops.** A discussion of the possibility of cranberry culture has already been presented. In addition to this our experiments with blueberries (the large hybrid varieties) have indicated that the mid-bog conditions are unfavorable. The soil of the Panicum consocies areas is much more favorable, but the best results were obtained in the coarse sands of the sand ridge areas, avoiding however, the white ridges proper and keeping the plants on the lower flat areas

where the wire grass shows a good growth. Areas where the permanent water table is from two to four feet beneath the surface should prove very favorable for these plants.

LITERATURE

The only citations given here are those in which the observations deal directly with the southern upland grass-sedge bog. These are for the most part descriptive accounts of general features and vegetation. It was deemed inadvisable to present a large bibliography covering the broader aspects of bogs, or the general literature on southern vegetation.

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SUMMARY

1. An intensive study from the successional point of view of the vegetation and habitat of an upland grass-sedge bog in S.E. North Carolina, is here presented.

2. The bog associes is divided into two consocies, viz.: Campulosus, the typical bog and Panicum, the transitional bog. Practically complete lists of species are given with anthesis data in case of the first. Remarkable fire repressed trees are described.

3. The two consocies are directly correlated in their distribution with the hydroperiod of the respective areas, the hydroperiod referring to the time the water table occupies a unit vertical zone (layer) of soil next to the surface. The index hydroperiod is the time taken for the

fall of the water table from the surface through a unit distance. In the Campulosus areas this was about twice that of the Panicum areas. This method furnishes a new way in which to quantitatively deal with the primary soil factor concerned in the development of the bog soil conditions. The basic factors of topography and soil which account for the long hydroperiods of the upland habitat, are discussed. Further the peculiar extension of the hydroperiod through capillary activity is described from porosity studies.

4. Quantitative data were also obtained for certain significant factors which follow as sequelae of the long hydroperiods.

5. The interesting lag or hold over effect of the bog factor complex when the hydroperiods are shortened is described and discussed.

6. The story of succession from the original shrub bog to the grass-sedge type is presented and the probable changes in the absence of fire have been worked out. The erosion succession is also fully treated. The probable role of the habitat factors in the seral progression is discussed.

7. Practical applications of the data obtained in this study are presented, such as the use of the native vegetation as indicators of drainage conditions, the value of making hydroperiod observations, and the importance from a soil standpoint, of preventing fires.